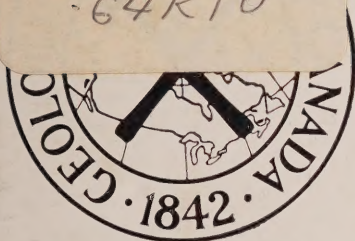


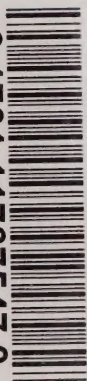
Government
Publications


WATERTON LAKES NATIONAL PARK

lakes amid the mountains



3 1761 11767547 0





Digitized by the Internet Archive
in 2023 with funding from
University of Toronto

<https://archive.org/details/31761117675470>

WATERTON LAKES NATIONAL PARK

lakes amid the mountains

David M. Baird



MISCELLANEOUS REPORT 10

Issued by
THE GEOLOGICAL SURVEY OF CANADA
Department of Mines and Technical Surveys, Ottawa
\$1.50

© Crown Copyrights reserved

Available by mail from the Queen's Printer, Ottawa,
from the Geological Survey of Canada,
601 Booth St., Ottawa,
and at the following Canadian Government bookshops:

OTTAWA

Daly Building, Corner Mackenzie and Rideau

TORONTO

Mackenzie Building, 36 Adelaide St. East

MONTREAL

Æterna-Vie Building, 1182 St. Catherine St. West

or through your bookseller

A deposit copy of this publication is also available
for reference in public libraries across Canada

Price: \$1.50

Catalogue No. M41-8/10

Price subject to change without notice

ROGER DUHAMEL, F.R.S.C.

Queen's Printer and Controller of Stationery

Ottawa, Canada

1964

Page

1	• INTRODUCTION
2	• DIVIDES
4	• BOUNDARIES OF THE PARK
6	• ORIGIN OF THE MOUNTAINS
15	• THE ROCKS
23	• THE SCULPTURING OF THE MOUNTAINS
29	• REGIONAL DIFFERENCES IN THE MOUNTAINS
31	• SHAPES OF MOUNTAINS
32	• Castellate, castle, or 'layer-cake' mountains
33	• Mountains cut in dipping layered rocks
34	• Dogtooth mountains
34	• Sawtooth mountains
35	• Irregular mountains
35	• Synclinal mountains
36	• Anticlinal mountains
36	• Mountains of complex structure
37	• Matterhorn mountains
38	• ROADLOGS AND POINTS OF INTEREST
38	• WATERTON PARK TOWNSITE AND NEARBY EXCURSIONS
38	• Shoreline of the main Waterton Lake near mouth of Cameron Creek
42	• Cameron Falls
42	• Trail to Bertha Lake
44	• Trail to Crypt Lake
50	• Trip along Waterton Lakes (southern lake)
53	• Trail from Waterton Lakes to Cameron Lake via Alderson and Carthew Lakes
59	• AKAMINA HIGHWAY TO CAMERON LAKE
59	• Viewpoint over northern end of townsite
63	• Falls on Cameron Creek and Oil City
65	• Cameron Lake

Page

ROADLOGS AND POINTS OF INTEREST (cont.)

- 68 • THE ROAD TO RED ROCK CANYON
- 68 • Junction of Red Rock Canyon road and main road
- 69 • Middle of long straight stretch
- 72 • Flat below red outcrops
- 72 • Copper Mine Creek
- 73 • Straight stretch on valley flat
- 73 • Red Rock Canyon
- 77 • Road and trail northwest from Red Rock Canyon
- 78 • Trail from Red Rock Canyon westward along
Blakiston Brook
- 80 • VIEWPOINTS ALONG HIGHWAY 6
- 80 • Northern entry on road from Pincher Creek
- 81 • Viewpoint on big bend
- 84 • Stop just east of Warden's station
- 84 • Belly River crossing
- 85 • Southeastern gate at United States border
- 88 • EPILOGUE
- 91 • INDEX

Cover—

Clouds cover the tops of the mountains on the east side of the main Waterton Lake in this view looking south from the Bear's Hump. The nearer half of the lake is in Canada, the rest is in Glacier National Park in the United States. The neatly laid out trailer areas stand out conspicuously in the town of Waterton Park. The town itself is built on the delta made by Cameron Creek and its ancestral glacial streams.

All photographs are by the author. Pen sketches of mountains are by D. L. Dineley, University of Ottawa.

Map and other illustrations are by Cartography Unit, Geological Survey of Canada.

How to Use this Book

Read it from the beginning. If you haven't the time immediately, look at the illustrations and turn to the map at the back to find the numbers of the stops along the route you are travelling. Then turn to the roadlog (starting on page 38) and follow each stop carefully, for you will find that the beauty of the scene is increased for the traveller who knows something of what he is looking at and how it originated.

The first part of this guidebook describes in some detail the general aspects of the geology of Waterton Lakes National Park . . . where it is, how the mountains there originated, what the rocks of the region are and where they came from, and the different shapes of mountains related to the structures of the rocks composing them. This general background is followed by detailed descriptions of selected localities of special geological interest. The last part comprises a series of notes on what is to be seen at each of the viewpoints and roadside stops along the main travel routes, with an index map to show where they are.

Most of the words used in a technical sense or which have an unusual meaning are explained carefully where they are first used. But if the meaning of a word is not immediately clear look in the index, for many of the unusual ones are listed there along with all localities and subjects.



Vimy Peak dominates the scene around the village of Waterton Park. It is made from great slices of rock that have been thrust up, one on top of another, and then deeply eroded. One of the planes of this thrust movement is marked by the light streak crossing more or less horizontally about a quarter of the way down from the top of the peak.

WATERTON LAKES NATIONAL PARK

is in the southwest corner of Alberta with its southern boundary along the United States border and its western boundary along the Alberta-British Columbia border. Its eastern and northern parts include part of the rolling grasslands of the great plains, and these give way along a fairly sharp line to the rugged peaks of the Rocky Mountains. The Waterton Lakes extend from south of the International Boundary to make a focal point in the park.

The mountains are sculptured from a great thickness of sedimentary rocks which were laid down in the seas that covered this part of North America more than a thousand million years ago, in a period of time which the geologist refers to as 'the Precambrian'. In some places the rocks are flat lying, even in the highest mountains; in others they are standing on edge or are intricately folded. In places they show great 'faults', or breaks along which one mass of rocks has ridden up over another. Deep erosion into this complicated mass of rocks has resulted in the array of mountain peaks—some with sharp jagged tops, others resembling castles or layer cakes, and still others with rounded contours. The sides of some of the mountains, extending as they do through thousands of vertical feet, expose many varieties of sedimentary rock and, here and there, thin sheets and masses of igneous rocks, which at one time were molten.

In the mountains themselves rivers and streams are busily carving their valleys even deeper at the present time. High

in the mountains the great bowl-shaped depressions, called 'cirques', commonly with small lakes in their bottoms, remind us of the glaciers that covered the whole of this area in the very recent geological past.

Thus, for the traveller who has time to look and the knowledge to see, Waterton Lakes National Park has, in addition to lovely scenery, many features of geological interest in the rocks into which the scenery is carved. In this book we will talk about the scenery and how it was made from the time the rocks were first formed to the present day. We will see that the beauty of the view is the result of a thousand million years of geological processes not unlike those we can see going around us in different parts of the world even now. But before we look into the ancient history of the park let's examine its boundaries to see exactly where it is. Because some of the park boundaries are divides, we should first find out what divides really are.

DIVIDES

Any stream, even the largest river, gradually gets smaller above the tributaries that pour water into it from the sides. Thus, even the largest rivers rise in a multitude of very small streams which make up the bulk of the main river by uniting their waters. If we travel farther and farther up a small stream we will eventually come to where it begins as a tiny trickle of water. Such a place is usually near the top of a hill, for as rain falls on the hill it will naturally flow down the slopes on all sides. Thus the crest of a ridge forms a natural divide between waters that flow down one side and

waters that flow down the other. This is why, on the ground or on a map, a line drawn to separate two drainage systems is called 'a divide'.

A look at a map of the whole of North America will quickly show us that some very large rivers flow into each of the oceans bordering this continent. If we were to follow these rivers to their very headwaters we would find it possible to establish a line separating the drainage to the Pacific Ocean from the drainage to the Atlantic Ocean, and other lines which divide Atlantic drainage from Arctic drainage and Arctic drainage from Pacific drainage. Thus we apply the term 'continental divides' to the imaginary lines that separate the major drainage areas of a continent.

Ever since man first began to separate territories it has been convenient to divide them on the basis of drainage basins of rivers. Boundaries of countries, provinces or even counties have commonly been defined as the divide between the water flowing to one side and water flowing to another. One such boundary is between the Province of Alberta and the Province of British Columbia. This divide, which runs right up the spine of the Rocky Mountains, separates waters that eventually end up in the rivers to the Pacific Ocean from those that will flow finally into the Atlantic Ocean. It is this same continental divide that forms the western boundary of Waterton Lakes National Park. This means that at any point on the part of the boundary made by the continental divide, a cup of tea spilled half on one side of the line and half on the other would eventually reach two different oceans. In fact there is one spot in North America where drainage is

split among three oceans, and from this spot—in the icefields where Banff and Jasper National Parks come together—your cup of tea could be spilled into the Arctic Ocean, the Atlantic Ocean, and the Pacific Ocean.

BOUNDARIES OF THE PARK

Waterton Lakes National Park is an irregularly shaped area tucked into the southwestern corner of Alberta. The southwest corner of the park itself is formed by the intersecting lines of the continental divide on the west and the Canada-United States boundary on the south—at this point the 49th parallel of latitude, an exact east-west line. Waterton Lakes Park extends for some 38 miles in an eastward direction along this southern boundary. From the southeast corner, only about a mile east of the Chief Mountain customs port where Route 6 passes southward into Montana, the border of the park extends northward along a surveyed line for about 10 miles. From here it goes generally northwestward for a distance of some 35 miles along a series of surveyed north-south and east-west lines which make a series of right-angled jogs, to a point on Yarrow Creek in the northernmost part of the park. The boundary then extends up Yarrow Creek to a tributary and along the tributary to the shoulder and eventually the crest of Cloudy Ridge. From here it follows a series of divides, first between the north-flowing waters of Yarrow Creek and the southeastward-flowing waters of Bauerman Brook, then between the waters of north-flowing Castle River and the headwaters of Bauerman Brook, to the northwestern corner of the park on the continental divide.



The quietly flowing waters of Waterton River about half a mile southwest of the park entrance reflect the grey mass of Vimy Peak. The gently rolling country around this point is underlain by slightly disturbed rocks which give way to the east to the nearly flat lying rock of the great plains. The mountains in the background however, lie on the other side of the "Lewis thrust" which marks an abrupt change to very mountainous country and rocks of complicated structure.

From the northwest corner to the southwest corner the park's border is the Alberta-British Columbia boundary (here the continental divide). Along this series of ridges and peaks the drainage to the east, which ends up in Hudson Bay via Saskatchewan River, is separated from drainage to the west which ends up in the Pacific Ocean via the Flat Head and Columbia Rivers.

ORIGIN OF THE MOUNTAINS

In an area like Waterton Lakes National Park which includes a small part of the rolling plains and a large part of rugged mountainous terrain, any understanding of the scenery requires a knowledge of how mountains originate.

Now, the surface of the earth has mountains of many different kinds: some stand as isolated masses whereas others occur in groups clearly related to one another; some tower thousands of feet above their surroundings whereas others (called 'mountains' by the people who live there) may be only a few hundred feet high. The wide variety of mountains points to a wide variety of origins.

In some parts of the world great masses of liquid lava and ash pour up from the depths of the earth to accumulate around volcanic vents. These are volcanic mountains. In other places, rivers and streams have cut deeply into high plateau areas over long periods of time to leave rough, mountainous terrain. In still other parts of the world, huge wrinklings in the earth's crust are made by tremendous compressive forces, in the same way that you can wrinkle the carpet on a floor by pushing against it with your foot. These

make folded mountains. Another type of mountain results in places where the earth seems to have split along enormous faults or breaks and one of the sides may be uplifted several thousands of feet. These are fault-block mountains.

When, however, we come to the great ranges of mountains—groups of clearly related mountains that extend for hundreds or even thousands of miles over the surface of the earth—we find a much more complicated story. One of the most interesting parts of this story is that the major mountain systems all over the world seem to have the same kind of history, with at least several chapters in common. We call this type ‘geosynclinal mountains’ and it will help to know something about how they originate, for the mountains in the western Canadian National Parks are of this kind.

To begin the story of these mountains we must go back into geological time about 1,000 million years. North America then was very different from the land we know today. Where we now find the Rocky Mountain System from the Arctic Ocean to Mexico, there existed a great flat area which was very close to sea-level. Great forces in the interior of the earth caused the whole area to sink very slowly below sea level. The rate of this depression was probably only a few inches in a thousand years but it continued over a long period. It meant that the sea eventually flooded the land over hundreds of thousands of square miles from the Arctic Ocean to the Gulf of Mexico. Into this vast shallow inland sea the rivers from the surrounding regions poured their loads of silt and mud, which spread evenly over the bottom.

Waves along the shores of these ancient seas eroded the land, added more sediments, and made currents to distribute them over the bottom, far from land.

As the millions of years passed, the accumulation of sedimentary materials—the mud, silt and sand from the rivers

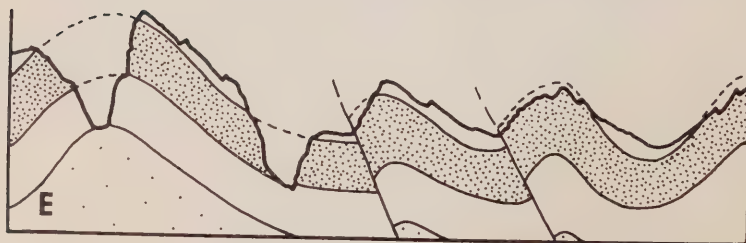
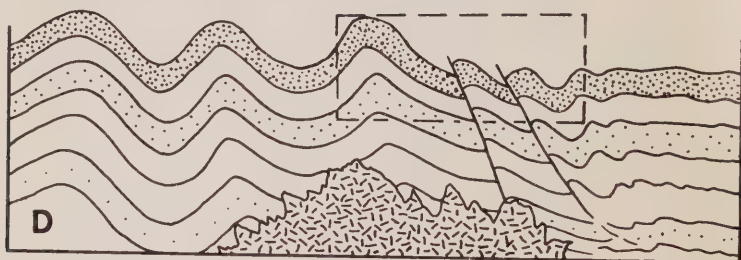
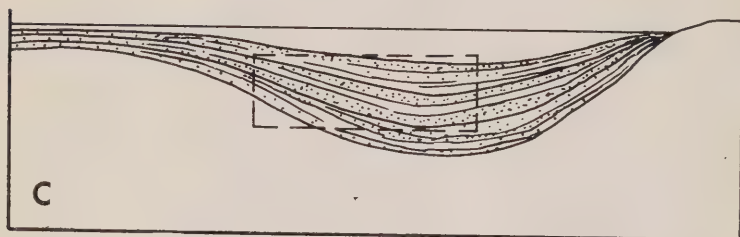
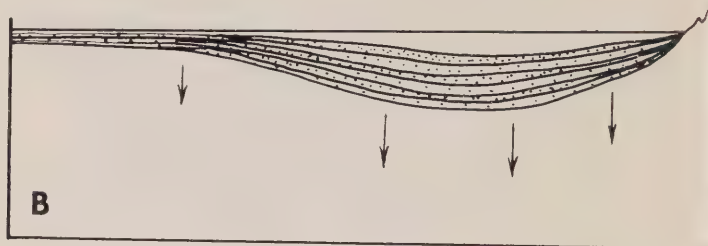
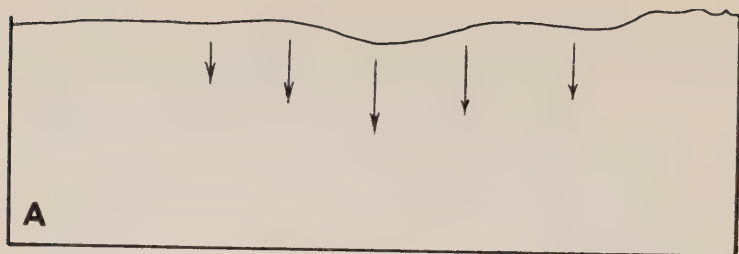
When Precambrian seas covered the area of what is now Waterton Lakes National Park, the sands, silts and muds from the erosion of adjacent landmasses were deposited. Waves rippled the bottom in places where the water was shallow. Now, a thousand million years later, we can find ripple-marked slabs of sandy siltstone—like this one which is covered by a variety of lichens—7,000 feet above sea-level on the south shore of the upper Carthew Lake.



and shorelines, and limy precipitates from the sea itself—gradually filled the shallow inland sea. At times, vast areas must have become filled up to near sea-level. But one of the strange things about these great depressions in the earth's surface is the way they seem to have continued to sink as the load of sedimentary material in their centres increased. By this gradual sinking and an almost equal rate of filling it was possible for thousands and thousands of feet of sand, silt and mud to accumulate, layer upon layer, and all show features of shallow-water origin.

At a time in the earth's history which geologists place at between 600 million and 500 million years ago, living things began to populate some parts of the seas fairly thickly. Some of these creatures had hard skeletons or outer coverings, and when they died these hard parts fell to the bottom and were promptly buried by the accumulating muds and silts. In some places the hard parts of the dead animals made clear impressions on the sedimentary materials on the sea bottom. When the soft sedimentary materials hardened into solid rock (over a period of millions of years), the remains of the long-dead organisms became fossils.

How do we know these things took place where we now find the western mountains? We read it in the rocks where the story is fairly clearly written. The rocks of which the mountains are made are distinctly of sedimentary origin—that is, they are made of ancient gravels, sands, muds and various sediments that have become hardened into solid rock. They are layered or stratified as we would expect accumulating sediments to be, because from time to time there were changes in the composition of the material being laid down.



Development of geosynclinal mountains:

The spectacular peaks and valleys of the Rocky Mountains as we know them today are made of rocks which record a story that began more than 600 million years ago. At that time part of western North America began to warp downward to form an elongated trough as in A.

Rivers poured sand, silt and gravel into the lowland area. Downwarping continued until the trough was filled with a shallow sea, into which poured a steady flow of sedimentary materials, as in B.

Downsinking continued, but it seems to have been at a rate that corresponded closely to the rate of filling, so that sedimentation was always into shallow marine waters. The mass of sedimentary materials slowly changed to sedimentary rock as the load on top increased until it had a form like that in C.

For reasons we do not yet understand the trough area was then severely compressed so that the rocks in it were folded and broken. At about this time in the history of such mountains great masses of molten materials commonly appear in the cores of the folded and broken rock, eventually solidifying into granite. D is what an enlarged section of C would look like.

Uplift accompanied the folding and faulting, and as soon as the rocks emerged from the sea they were subjected to erosion. Rivers and glaciers carved the valleys and formed the peaks as shown in E, an enlarged part of D. This is the stage of development of our Rocky Mountains now.

These changes may have been due to storms, changes in wave patterns, changes in drainage systems, or the changes that would take place as the land supplying the sediment was gradually being eroded away. On some of the rock surfaces we find ripple marks which are exactly like those found today in stream bottoms or in the shallow parts of the sea. Some of the surfaces are dimpled with impressions of raindrops and mud-cracks as though they had been exposed at low water. Impressions of salt crystals on some beds suggest that drying went on for quite a long time. By splitting open the rocks we can find the fossilized remains of ancient sea creatures, some of them with modern counterparts. Other fossilized skeletons are from creatures that have been extinct for millions of years; yet we can tell a great deal about them by comparing their structures with those of living creatures and noting carefully their association with creatures we know something about.

The kinds of materials the rocks are made of and all the structures found in them can be observed today in different parts of the world in the actual process of formation. We can estimate the extent of the ancient seas by looking for the rocks that were deposited in them. We can tell something of the existence of former shorelines by looking for evidence of beach deposits in the rocks. We can tell whether rocks were laid down as sediments in deep water or in shallow water by comparing what we find in the rocks with what we see being deposited in those environments now.

As to the development of the Rocky Mountains we can conclude, by observing evidence of erosion still preserved in the rock record, that the seas withdrew temporarily from

the region or that the sediments completely filled the shallow depression on the top of the continent. In short, by putting together and correlating hundreds of small pieces of scattered evidence we can unravel with some certainty the story of the rocks from which the mountains were later carved.

The next chapter in the history of the Rocky Mountains seems to have begun about 200 million years ago. The rock record tells us that a disturbance of the very shallow depression on the surface of western North America, which, as we have observed above, became filled with sedimentary materials, began to change the pattern of development. Some areas of the old trough were lifted up out of the sea and were themselves eroded to supply sediments that were poured back into the remaining sea.

As the tens of millions of years passed the crust of the earth apparently became more and more unstable in the region of what we now call the Rocky Mountains. This unrest culminated about 75 million years ago in a complete change. From the Arctic Ocean to the Gulf of Mexico the great thickness of rocks which had been accumulating as sediments on the old sea-bottom in the previous billion years, was lifted above sea-level, broken in many places along great fractures called 'faults', and, in some places, strongly compressed. The compression or squeezing caused the great blanket of rocks to fold and buckle, and, in places, to break so that one part slid up over another part. The forces within the earth that would cause this kind of uplift and breaking are so vast that it is difficult to comprehend them at all.

Yet we can go to the mountains and once again clearly see proof of this chapter in the development of the Rocky Mountain System.

In very old mountain systems of the world, where long-continued erosion has cut into the very core of the mountains themselves, we can often observe in some detail a third chapter in the development of geosynclinal mountains. It seems that during or just after the folding and faulting, great masses of hot molten rock appear in the cores of mountain systems. These push rocks aside or melt their way into the interiors of the belts of folded and broken sedimentary rock, where they cool down and eventually solidify. Canada's Rocky Mountains have not been deeply enough eroded so we know nothing of this part of their history.

The next phase in the development of all geosynclinal mountain systems seems to be one of quiet stability, during which the agents of erosion, glaciers, rivers, and wind contrive to cut deeply into the uplifted, complicated mass of broken and folded rocks. For some 70 million years now this has been the history of the Rocky Mountains in Canada.

At the present time, as we drive through the river valleys and among the mountain peaks, we can observe erosion as it proceeds. We can actually watch the glaciers pushing and scraping over the country, tearing off rock and grinding it up, some of it as fine as flour. We can see the rivers cutting into their rocky courses, wearing away the land, and carrying their loads of debris towards the ocean. We can observe great masses of gravel, sand and silt—the result of erosion of mighty mountains through tens of thousands of years—

now spread out below the foot of the mountains. And we can see where erosion has cut valleys deep into the complicated rock structures to reveal much of the story of folding, faulting and uplift.

THE ROCKS

We have already seen how the rocks in Waterton Lakes National Park were almost all laid down as sediments in a succession of seas that covered the area in the very distant geological past. Now let's examine these sediments and the rocks that resulted from their consolidation, and also find out how the thin masses of igneous rocks which seem to have been molten at one time came to be where we now find them.

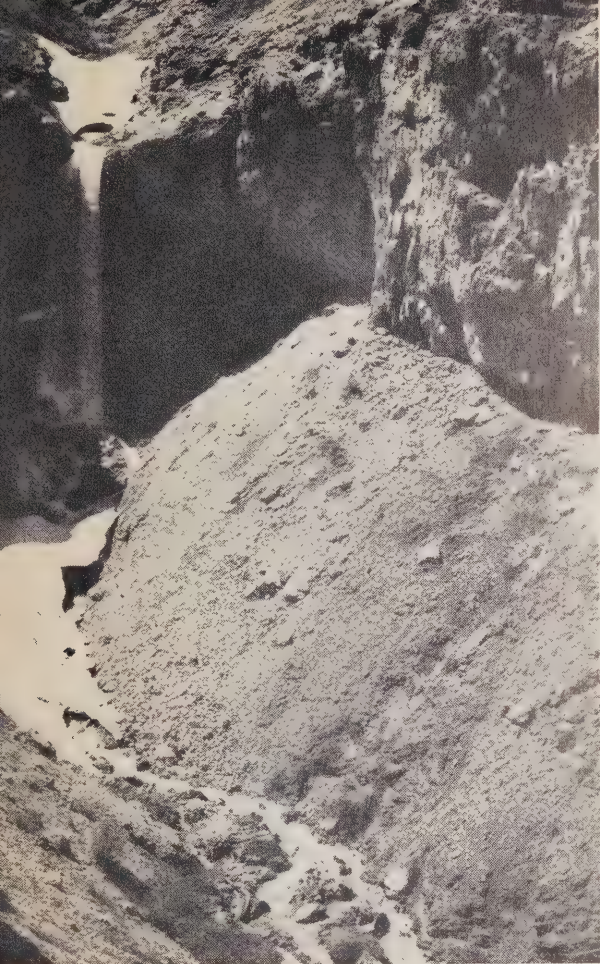
If we could find a place in the park where a drill could penetrate the entire rock section—from the very youngest rocks on the top to the very oldest ones deep below—we could study the whole history in one place. But because these rocks have been folded and broken along great splits or faults, this is not possible. We can, however, piece together the broken parts of the record from different areas and thus figure out almost exactly what the whole sequence of rocks looked like before it was broken. Within the rock sequence, units of various sizes with different names occur.

It is the custom of geologists to give names to rock units: they are named after the place where they were first discovered and described, or after the place where they are best exposed. Where there are masses of layered rocks

geologists use different names to indicate the different layers and groups of layers. An individual layer may be called a "bed" or "stratum"; thus we might refer to a "limestone bed", a "limestone layer" or a "limestone stratum". A group of such beds, layers, or strata that have some distinctive character in common throughout, is called a "formation". An example in Waterton Lakes National Park is the Waterton Formation—named for its occurrence near the village of Waterton and consisting of a number of beds or layers that have a generally similar age, composition, and appearance. A still larger unit of rock layers is termed a "group". Now, having looked at how geologists name rock units, we can look at some of the rock types and the units into which they are grouped in the park.

Under ordinary circumstances you would expect to find in any sequence of layered sedimentary rocks that the youngest rocks lie on top and the oldest rocks below. This is known as the "law of superposition" and you can easily see why it would usually apply by thinking of how these rocks originate—accumulating in layers, one after another, of sand, silt, mud and gravel on the bottom of the sea. When a road is built a layer of coarse gravel may come first, followed by fine sand, then crushed stone, then coarse asphalt, with fine asphalt on top. If you were to cut down through the road or bore a hole in it it would be obvious that the 'youngest layer' is the top coat of asphalt and that the first layer put down, the 'oldest', is the coarse gravel on the bottom.

A study of the geology of southwestern Alberta shows again and again that the great mass of sedimentary rock that



Hell Roaring Creek falls over a heavy limestone-dolomite rock bed of the Waterton Formation into a gully worn in argillites of the Grinnell Formation below. In this area great sheets of rocks were pushed over one another along fault planes. The Mount Crandell thrust, one of these fault planes, occurs along the bottom of the limestone-dolomite mass and separates it from the sheared and broken argillites below. It is the same thrust surface that is seen high up on the front of Vimy Peak.

underlies the plains area farther east in a more or less flat undisturbed sequence, has been severely folded and broken along 'faults' by enormous compressive stresses somehow related to fundamental forces deep within the framework of the earth. Compression has even gone farther than folding and breaking the rocks for we can see abundant evidence that great masses of rocks have been pushed up and over other masses of folded and broken rocks, so that in some

places older rocks lie on top of younger ones. As a result of all these processes some of the oldest rocks—rocks that we would normally expect to occur only deep below the surface of the ground—are now found high on the mountain peaks. Conversely, to find out what lay above some of these ancient rocks in the original sedimentary layered sequence we have to travel out to the plains and drill into the topmost layers there. Thus the sorting out of the original sequence in Waterton Lakes National Park has been a complicated problem for the geologists who have worked there.

The oldest rocks in the district belong to the Purcell Series, which consists of several thousand feet of sedimentary rocks divided into an upper and lower part by a dark-coloured, purplish green, lava flow. All these rocks were laid down in that part of Precambrian time between twelve hundred million and a thousand million years ago.

The oldest exposed rocks of the lower parts of the Purcell Series have been called the “Waterton Formation”, consisting of various kinds of dolomite, limestone and argillite. They may be seen at Cameron Falls in Waterton village, along the west shore of the main (southern body) of the Waterton Lakes for about a mile on each side of the mouth of Bertha Brook, and in the lower part of the south side of the point of land more or less opposite Waterton village. The rocks of the Waterton Formation are succeeded by those of the Altyn Formation, the Appekunny Formation, the Grinnell Formation, and the Siyeh Formation. These formations consist of several varieties of dolomite and sandy dolomite, red and green argillite, quartzite and various limestones including some which are full of concentric structures

of probable plant (algal) origin. The Appekunny Formation is noteworthy in that it forms the greenish grey and red dish cliffs seen in many of the prominent mountains in the Waterton district. It is well displayed in the lower and middle slopes of Vimy Peak opposite Waterton village, and in Ruby Ridge where the bright red argillite of the overlying Grinnell Formation is also seen. The upper Purcell rocks are divided into the Sheppard Formation below, consisting mostly of brown-weathering dolomites and argillite and the Kintla Formation above with red and green argillite and quartzite. The spectacular red 'scree' and debris slopes in the neighbourhood of the upper Carthew Lake are in the Kintla Formation.

The layered sedimentary rocks of the Altyn, Appekunny, Grinnell and Siyeh Formations have been intruded by thin sheets (called "sills") of a dark green, massive igneous rock called "diabase" or "gabbro". This rock, which appears to have been molten at the time it was injected, seems to have worked its way along certain layers and lifted the overlying load to make room for itself and then solidified slowly to form the solid igneous rock we find there today. In some places the heat from the cooling igneous mass has bleached the rock above and below it. Thus the sills that now appear in the mountain sides as dark streaks parallel to the sedimentary layering may have light-coloured, bleached margins. Excellent examples are seen from Waterton village in the steep upper slope of Mount Cleveland which is far south of the United States border but is clearly visible, in the steep cliffs on both sides of Alderson Lake, in the cliffs of Mount Blakiston, and in the upper parts of Anderson Peak from Red Rock Canyon.

In the eastern sections of the park the rocks are quite different from those exposed in the mountains. Here and there, in streams and in occasional road-cuts, outcrops of sandstone and shale in a friable and broken condition are considered by geologists to be very much younger than anything seen in the mountains. These rocks almost all belong to the Belly River Formation and the Wapiabi Formation which are of Cretaceous age—that is they are about one hundred million years old.

From what surface information there is available and from that derived from holes drilled deep into the rocks for oil, it appears that the rocks in the undulating foothills and the near parts of the plains consist of a great series of 'fault slices' lying like shingles on a roof, with each one overlapping the next. Each of the faults appears to dip or slope generally westward with a flattening in depth. Onto this complicated mass of shingle-like slices, another tremendous series of slices of old rocks, brought up from the depths below, has been thrust eastward so that old rocks now lie on top of young rocks. The principal surface of this fault along which this riding-up-and-over motion has taken place is known widely in Alberta and Montana as the "Lewis thrust". Its 'trace', or the line where it becomes apparent at the surface, marks the front of the steep mountains for many tens of miles and it is responsible for the sudden change of rock types and the sudden change of scenery as well. It seems likely that the old rocks were thrust much farther east than is now seen and that they have been gradually eroded back to their present line. Chief Mountain, just south of Waterton Lakes National Park in Montana is an erosional remnant of this once more extensive 'thrust sheet'.



The limestone, dolomite, and argillite of the Siyeh Formation are locked to thick masses of dark green basalt which appear to have been squeezed in between the sedimentary layers in a hot molten condition and then crystallized. One of the basalt layers is exposed in this cliff on the northwest side of the trail leading up from Alderson Lake toward Caribou Lakes.

Within the great mass of old rocks thrust up on top of the younger Cretaceous rocks along the Lewis thrust, other thrust faults have been recognized, most noteworthy the Mount Crandell thrust. From Waterton village the Mount Crandell thrust can be seen clearly in the upper slopes of Vimy Peak where a band of light-coloured broken rock marks an abrupt change in both scenery and rock types. Above the Mount Crandell thrust, massive dolomite of the Altyn Formation makes more or less vertical cliffs, while below it the red, green and grey argillites of the Appekunny Formation have quite a different appearance. From Waterton village and from the road to the northeast a layer of bright red argillite of the Grinnell Formation in the face of Vimy Peak is visibly cut off toward the right or southwest at the thrust surface.

The forces that cause these thrusts and move the enormous quantities of rock over them for many miles are too large for our ordinary comprehension. We can only study the results of these powerful events and wonder at the source of the energy.

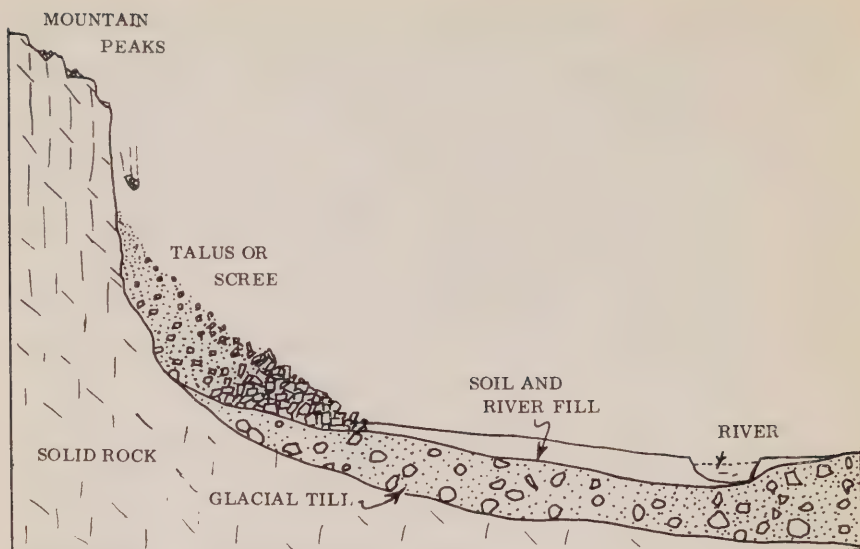
We have now seen what the rocks are made of and how most of them were laid down in seas that covered this area more than six hundred million years ago. We have seen also how thin masses of igneous rocks squeezed into the sedimentary pile in the molten state and solidified to make sills, and how the whole mass of rocks has been folded, faulted, broken and compressed. Now we shall examine how this mass of complicated rocks was carved into the mountains and valleys we see there today.

THE SCULPTURING OF THE MOUNTAINS

As soon as the rocks were laid bare by the retreat of the seas in which they were laid down they were subjected to the ever-present erosive action of rain, running water, falling snow, moving ice, frost, and chemical decay. Of all these agents of erosion, running water has been by far the most important in the carving of the mountains as we know them. For millions of years streams have carried away the debris of all the other agents of decay and erosion, and have themselves carved their valleys deep into the landscape.

The story of water erosion may begin on the highest peak. The freezing of a thin film of water under a boulder may wedge it out and tumble it over the edge of a cliff. Heavy rains may loosen rocks and boulders or may lubricate others so that they too join the downward rush. Thus, bits and pieces of rocks are torn from the solid mountains and begin their long journey to the sea.

Their first resting place may be in one of the long fan-shaped accumulations of angular blocks and pieces of rock which we can see on the sides of every steep mountain. These are called 'talus' or 'scree' slopes, and their steepness is generally the maximum angle at which the loose rubble is stable. Climbing on them may be very difficult, particularly on the lower parts which consist of very large, angular boulders and chunks of rock lying in all attitudes where they have rolled or fallen. This means that not only will the surface of the talus or scree slope be very rough and irregular, but slight disturbances—even the passing weight of a man—may cause more sliding and adjustment of the blocks and particles in it.



A common sequence of erosion in Rocky Mountain country begins when boulders and smaller particles of rock are wedged off the bare rocky peaks and fall to the talus or scree slopes below. Physical and chemical breakdown of the rocks in the talus produces fine-grained materials which move in the wash of rain and in streams, towards the river. A layer of glacial till made of a mixture of boulders, sand and clay commonly blankets the solid rock underneath the soil and river-fill in such valleys. In many places the glacial till is actively eroded by the river and thus contributes directly to the load of sediments on its way to the distant sea.

Rivers may wash the bottoms of the talus slopes and carry off some of the boulders and rubble, so that angular pieces and fragments from the talus now become part of the mass of boulders, gravel and sand in the bottoms of stream valleys. Constant rubbing of boulders and pebbles against one another gradually wears them down and the fragments become very finely divided rock flour that looks like mud or silt in the water of the stream. Thus, over the ages, the mass of rocks in the mountains is gradually worn away by

the forces of erosion and carried ultimately to the sea, where it rests on the bottom as mud, silt or sand.

In regions where mountains are being folded and faulted, broken and uplifted, various agents of erosion may carve a whole set of valleys and mountains at one stage of development only to have their work completely changed by further uplift, movement along the surface of faults, and folding of the rocks. Another cycle of erosion may reshape and completely modify the outlines of the mountains and valleys of the previous cycle.

Thus, in the Rockies, after a long period of repeated uplift with intervening periods of erosion, great valleys were carved and the main outlines of the mountains as we know them were shaped by the action of running water. After this there came a period in very recent geological time when the whole of northern North America was covered by a great ice-cap, rather like those on Antarctica and Greenland today. It is thought that this period of glaciation began about a million years ago. It left its mark on the land almost everywhere we look.

Glacier erosion is of two kinds. When an area is covered by an ice-cap, more or less evenly, the movement of ice outward from the centre of accumulation of snow tends to round off the bumps and smooth out the hollows. High in the mountains, however, the action of the glaciers is generally much more localized and accentuated. Around the margins of snowfields or icefields, glaciers push down the valleys, steepening them and deepening them as they go. In the area of accumulation, great bowl-shaped depressions--called

‘cirques’—are sometimes carved deep into the mountain-sides. These commonly have almost vertical back walls and rounded bottoms. The cutting action caused by the movement of ice and snow toward the centres of cirques and the outlets of snowfields tends to steepen the scenery in the mountains and make it much more sharp and angular. If, for example, cirques are being cut into two opposite sides of a mountain, the two vertical back walls may happen to intersect one another, leaving a razor-sharp rock ridge. It sometimes happens that a rounded mountain-peak of considerable elevation is cut into by cirques from several sides. This process may leave semi-pyramidal towers of rock, like the world-famous Matterhorn, or Mount Assiniboine in the Canadian Rockies.

Long tongues of ice extending from snowfields down the valleys as valley glaciers commonly steepen the valley walls, pushing great piles of rock rubble and debris ahead of them. The position of maximum penetration of such alpine glaciers is commonly marked by great heaps of the debris they have left behind. Long finger lakes are sometimes found in valleys that were dammed up in this way, but in others the rivers were able to cut through the dams and drain the upper valleys.

Farther back, where the valley walls were much steepened, characteristic U-shapes are impressed on the valleys and the bottoms are covered with blankets of glacial debris. Small streams, occupying shallow valleys on the shoulders of the main valleys, may now tumble over the edge in very high waterfalls. The high valleys that the streams run in are called ‘hanging valleys’.



The valley now occupied by the main Waterton Lake is the valley of an ancient river, widened and deepened by glaciers. This scraping out of the main valley left small tributary valleys 'hanging' on its sides. Brooks coming down the tributary valleys now plunge over the steepened walls to the level of Waterton Lakes. This is Hell Roaring Creek a few hundred feet east of the shore of the main Waterton Lake.

Thus we can see how glaciers tend to sharpen up the profiles of the mountains and the scenery. Bowl-shaped depressions with vertical walls (cirques), sharp ridges with nearly vertical sides, sharp angular mountain peaks, U-shaped and hanging valleys—all of these are characteristic of areas of upland glaciation. Nowadays in Canada's western mountains we can see a few remnants of the ice that covered the whole area in the not very distant geological past; these are the glaciers and snowfields still left on the heights and in protected places.

In the few thousands of years since the glaciers modified the shape of Canada's western mountains, rivers have resumed the carving and cutting of the great mass of uplifted rock. Now, however, their valleys are choked with glacial debris brought from higher places by the moving ice. In some places the cirques or bowl-shaped depressions carved by the glaciers are occupied by small lakes called 'tarns', and in other places the long valleys have filled with water and are now long finger lakes.

The glacial litter—the vast quantity of sand, gravel and ground-up rock—is in some places distributed and redistributed by flowing rivers over flat valley floors to make braided streams. In summer, when meltwaters from the glaciers and the snowfields make the rivers high, you can imagine what an enormous load of rock debris is being carried to the sea each year from the wasting mountains.

Marks of the passing of the glaciers are visible everywhere in Waterton Lakes National Park. The main Waterton Lake itself seems to have been filled at one time by a great glacier

which spilled out over and around a point of rock opposite Waterton village into the bowl now occupied by the outer part of Waterton Lake, and thence to the plain. Steepening of the cliffs along its sides left small tributary valleys partly hanging, so that falls like Cameron Falls and those at the mouth of Hell Roaring Creek are common. The mountains all through the park are characterized by cirques and glacially steepened walls. Masses of debris carried by the glaciers from the mountains are common in the valleys and along the fronts of the steep mountains.

REGIONAL DIFFERENCES IN THE MOUNTAINS

The western mountains of Canada show a distinct zoning from east to west at many different places along their length. Undisturbed flat-lying rocks underlie the western plains from Manitoba to near the western boundary of Alberta. To the west this area is succeeded by the Foothills, a region of folded and faulted rocks which have not been greatly uplifted. Still farther west, the Front Ranges of the Rocky Mountains succeed the Foothills along a very sharply marked boundary line. The Front Ranges are made of a series of fault slices of folded and broken rocks thrust together so that they overlap like the shingles on a roof.

The region of the Front Ranges is separated fairly clearly from another zone of mountains to the west—the Main Ranges of the Rocky Mountains. Here the rocks at the surface are relatively undisturbed although very much uplifted and deeply eroded. This we can tell because they include some of the oldest rocks exposed in the Rocky Mountain System. Farther west again are the Western



This cross-section through the Rocky Mountains, from the Plains to their western boundary, is greatly simplified to show the main features of their structural framework. In the east (the right in the diagram) flat-lying sedimentary rocks lie under the Plains layer upon layer, thousands of feet thick. In the Foothills the rocks are broken into steeply dipping slices, tilted so that each layer dips to the west, and uplifted so that rocks are brought from the depths up to or close to the surface.

The Front Ranges are made of slices of severely folded and faulted rocks which are uplifted and eroded so that layers that once were deep beneath the Plains are now at the surface, and in the valleys older rocks may be seen lying on top of younger rocks along each of the fault planes.

The simpler Main Ranges of the Rocky Mountains lie to the west of the complicated structures of the Front Ranges. They are cut into masses of sedimentary rocks which have not been severely folded but have been uplifted high into the air. Erosion has stripped off younger rocks and today we can see the flat-lying older rocks high in the peaks.

The Western Ranges are cut into fractured and folded younger rocks. The western boundary of the Rocky Mountains is the 'Rocky Mountain Trench', indicated by the dotted pattern. It is filled with thick deposits of sands and gravels and is occupied by major rivers like the Kootenay, the Columbia and the Fraser.

Ranges of the Rocky Mountain System, built along a belt of severe disturbance in which the rocks are broken, faulted and severely folded.

Waterton Lakes National Park lies along the eastern edge of the Front Ranges of the Rocky Mountain System. The mountains here, though, are different from the Front Ranges seen in Jasper and Banff National Parks. In Jasper and Banff the mountains are typically in long subparallel rows with open valleys between them, because in the more northern parts the thrust movement has been taken up along a number of fairly steep dipping faults. In the region of Waterton Lakes Park, however, the complex of older rocks has been thrust over the great break (the Lewis thrust) which is very nearly flat here. Within the mass on top of the Lewis thrust other faults are also fairly flat. This accounts for the general shapes of the mountains, which seem to be cut into rocks of generally flat dips except near faults where they are considerably folded and broken. It also accounts for the difficulty in finding any one mountainside in which a complete section of the rocks, from the oldest to the youngest, may be found.

SHAPES OF MOUNTAINS

Travellers in the mountains have long noted the distinctive shapes of individual mountains. These are due to combinations of three things: the kinds of rocks that go to make up the mountain, the structure of the rocks within the mountain, and the particular tools or agents of erosion which have carved the mountain (in the case of the mountains in

Canada's western parks, the rivers and glaciers). An assortment of rock types and structures which vary from flat-lying to vertical and from parallel-layered to crumpled and folded, has contributed to the many different shapes of the mountains we see in Waterton Lakes Park. The hundreds of peaks and mountain masses, however, belong to only about eight kinds—the ones you see sketched here.

Castellate, castle, or 'layer-cake' mountains

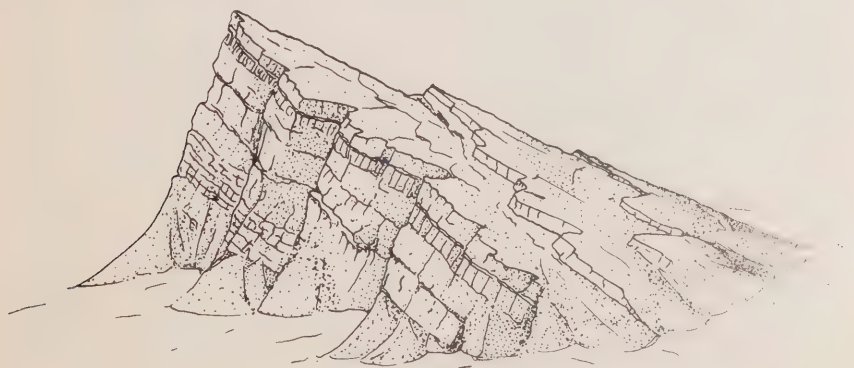
Mountains that are cut into more or less flat-lying sedimentary rocks commonly have profiles in which vertical steps alternate with flat or sloping terraces. Some such mountains look very much like ancient castles and are thus said to be 'castellate' or 'castle' mountains. Mountains of this kind are best developed in regions underlain by great thicknesses of rocks in which beds of massive limestone and sandstone or quartzite alternate with less-resistant shale or slate beds. The softer beds are eroded more rapidly, so that



the harder beds are undermined and tend to break off at right angles, forming steep slopes and cliffs. Steep-sided needles and pinnacles are sometimes left on the tops of such mountains as the uppermost massive layers are cut away. Mount Eisenhower, Pilot Mountain, the Cathedral peaks, Mount Saskatchewan and Mount Stephen are well known examples in the Rockies. The tops of Mounts Blakiston and Dungarvan are castellate mountains in Waterton Lakes National Park.

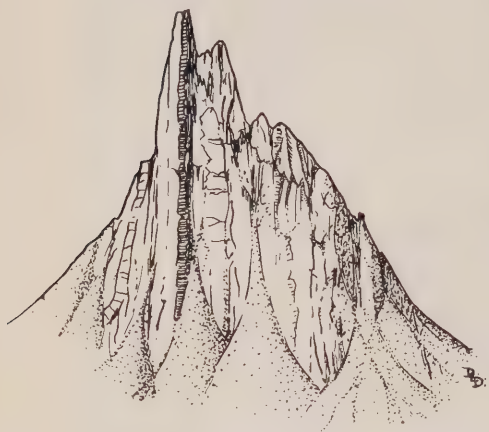
Mountains cut in dipping layered rocks

Some mountain peaks are cut into masses of layered sedimentary rocks which 'dip' or slope from nearly horizontal to 50 or 60 degrees. Some of these, like Mount Rundle near Banff, have one smooth slope which follows the dip of a particular rock layer from its peak almost to its base, and, on the other side, a less-regular slope which breaks across the upturned edges of the layered rock units. Other mountains, like Mount Edith Cavell, are cut into dipping sedimentary rocks in such a way that neither side follows the dipping



rock layers, and thus both sides are irregular. Mount Alderson, northwest of Waterton Lakes Park, is another example.

Dogtooth mountains



Sharp jagged mountains sometimes result from the erosion of masses of vertical or nearly vertical rock. The peaks may be centred on a particularly resistant bed, in which case a tall spine or rock wall may result. Some of the peaks in the Amiskwi area of Yoho National Park are of this kind.

Sawtooth mountains

If the rocks in a long ridge are vertical, erosion may produce rows of angular mountains that look like the teeth in a saw. This type can be seen in the Sawback Range near



Mount Eisenhower in Banff National Park, and in the Colin Range east of Jasper.

Irregular mountains

Many mountains are cut into more or less homogeneous masses of rock and, as a result, have no particularly characteristic shapes. These we may call 'irregular mountains', although individual peaks may be round, conical, pyramidal or quite shapeless, depending on how they were cut. Ruby Ridge in Waterton Lakes Park is an example.

Synclinal mountains

Mountains are very commonly carved out of masses of rocks that have been folded into great arches and troughs.



Erosion over long periods may cut away all the surrounding rocks to leave a mountain with a trough or bowl structure within it. This probably comes about because the folded rocks in the centre of the trough, which is called a 'syncline',

are more resistant to erosion than those in the surrounding parts, which tend to split and break during folding. Mount Kerkeslin in Jasper National Park is an excellent example of a synclinal mountain.

Anticlinal mountains

In some regions of folded rocks, mountains are underlain by great up-bowed or arched masses of rock. Such upfolds are 'anticlines' and the mountains are called 'anticlinal mountains'. Stretching of the rocks on the outside or upper



layers results in numerous fractures which in turn make the rocks very susceptible to erosion, so that true anticlinal mountains are rare, although several good examples are known in the Front Ranges of Jasper National Park.

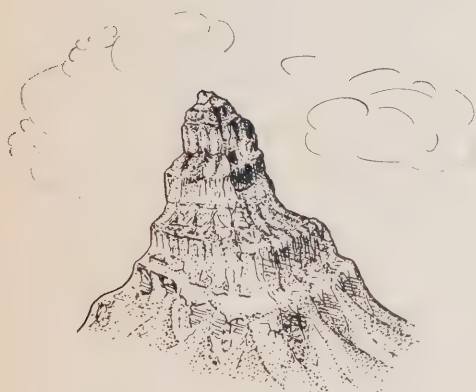
Mountains of complex structure



Anticlines and synclines, that is upfolds and downfolds, with or without breaks called 'faults', may be seen in the flanks of

some mountains that have been developed on tightly folded rocks. These we may call 'complex mountains' because of the complex structure of the rocks within them. Magnificent examples can be seen all along the eastern edge of Jasper National Park, in Mount Crandell in Waterton Lakes Park where the rocks are severely folded and faulted, and in Vimy Peak where several 'thrust sheets' of rock lie one on top of another.

Matterhorn mountains



When glaciers cut deeply into rocks that are more or less homogeneous they carve bowl-shaped depressions called 'cirques'. When several cirques cut into a mountain mass but are stopped by a warming of the climate and consequent melting, they sometimes leave sharp, semi-pyramidal towers of rock to which the general term 'matterhorn' is given. Mount Assiniboine is an outstanding example in the Canadian Rockies.

ROADLOGS AND POINTS OF INTEREST

WATERTON PARK TOWNSITE AND NEARBY EXCURSIONS

(1) Shoreline of the Main Waterton Lake near Mouth of Cameron Creek

At one time in the geological past, Cameron Creek carried much more water than it does now because all of its head-water brooks drained areas containing large melting glaciers. The melting glaciers also fed large quantities of sand, gravel and boulders that were rushed along the creek bed, through the canyons and over the falls, to spread out in a delta in the main Waterton Lake. The townsite is now built on these sedimentary materials which, from any viewpoint in the hills around, clearly show the delta's shape. This delta or fan is but one of several deltas that can be seen along the length of the lake. Cameron Creek itself is now captive and it flows between man-made walls all the way down from the falls to the main lake, no longer wandering over its delta in different places as it once did, although occasionally it goes wild in times of flood as it did in 1964 when it poured a mass of sand and boulders into the townsite.

From the shoreline a spectacular view down the lake shows mountains one after the other on both sides, receding into the distance. They are cut into a mass of rocks (called the "Purcell Series") of Precambrian age, about one thousand million years old. In ancient times when these rocks were laid down, all of this part of North America lay under a shallow sea in which fine, limy, marine muds were deposited and into which sands and gravels were

being poured by streams from adjacent landmasses. During and after deep burial these sediments turned to solid layered rocks. They were later intruded by thin sheets of molten rock which came from the depths of the earth under enormous pressure to work their way along between some of the beds or layers of the rocks already there. A spectacular exposure of one of these sheets, called "sills", may be seen in Mount Cleveland—the tall pyramidal peak far beyond the end of the lake and to the left or east as you look at it from Waterton. In the great cliff below its summit a dark layer of the formerly molten rock parallels the flat sedimentary layering. Bleaching of the rocks both above and below the igneous layer resulted from the great heat and the igneous juices leaking out from it. The white streaks are clearly visible, even from this distance.

On the right or western side of the lake great spikes stand up on Citadel Mountain and may be seen to be erosional remnants of a layer that once extended as a continuous mass. The International Boundary cuts almost at right angles across the length of the main Waterton Lake, just this side of the Citadel Mountain.

The great trough in which Waterton Lake lies probably began its history as a river valley prior to the great glaciation of northern North America which began about a million years ago. As the climate of this part of the world gradually cooled, snow accumulated in ever-increasing quantities, then turned to ice under its own weight and moved down from the mountains into the valleys below. Eventually the whole country was covered by an enormous ice-cap that moved over the face of the land carrying everything loose



Cameron Falls, at the northeast corner of the townsite of Waterton Park, is formed where Cameron Creek plunges over the steepened walls of the main Waterton Lake valley. The falls is now separated from the Lake by the width of a delta built by Cameron Creek at a time when it was receiving large quantities of debris from the melting glaciers higher up its valley.

before it and under it and greatly modifying the landscape. When the climate finally changed and the glaciers began to melt more rapidly than they accumulated, much of the land was uncovered until only the main valleys were occupied by great tongues of ice whose source areas were high in the mountain. These tongues of ice profoundly altered the shapes of the valleys they occupied, deepening them somewhat and greatly steepening their sides.

Thus the ancestral river valley now occupied by Waterton Lakes was deepened and steepened so that when the glaciers finally disappeared completely an elongated basin had been formed. This basin was partially dammed by glacial debris at its northern end, and as the brooks and rivers reoccupied their valleys, it gradually filled with water to form the lakes we see now. Small tributary valleys on the sides of the main valley were not as deeply eroded by moving ice, so that brooks that later occupied them now fall over the steep sides of the main valley in picturesque waterfalls.

It is intriguing to sit on the beach here on the side of the lake on a warm summer's day or even when the cool winds are blowing off the water, and realize that the magnificent scenery all around has had such a long and interesting geological history—beginning a thousand million years ago with ancient seas and the muds in their bottoms, extending through a period of profound glacial erosion, and still going on around us now as brooks carve their valleys and the waves on the lake cut into the shoreline or build beaches.

(2) Cameron Falls

The waters of Cameron Creek plunge swiftly along through a narrow canyon that is cut in rocks of the Waterton Formation, then over sloping ledges of brownish yellow dolomite onto the level of the upper end of their own delta at the northwest corner of the townsite of Waterton Park. It seems likely that the glaciers moving down the main valley of the Waterton Lakes pushed against the banks at this point, steepening them considerably. When Cameron Creek resumed its course after the glaciers had left, it found itself 'hanging' above the level of the main Waterton Lake. The first waterfall formed in this way was probably several times the height of the present Cameron Falls and the cutting of the canyon above the present falls must have reduced the height of the falls by as much as it is deep.

It is also probable that very large quantities of water came over the falls at this early stage of development, for melting glaciers in all the surrounding hills must have supplied great floods of water every spring. These fast-flowing meltwaters carried with them large quantities of sand and gravel which spread out at the level of the lake to form the delta where the townsite is now built.

As time goes on it is likely that the falls will wear back gradually until eventually they disappear, while the canyon above them will become that much deeper.

(3) Trail to Bertha Lake

A horse and walking trail leaves the southern corner of Waterton Park townsite and goes along the west shore of



The upper part of the main (southern) Waterton Lake occupies a very narrow valley which was deepened and widened by the passage of glaciers. The great wall of rock leading to Bertha Peak stands above the valley of Bertha Brook in this view from high above the east shore of the lake.

the main Waterton Lake southward to beyond the International Boundary. About a mile south of the townsite a branch trail leads westward into the valley of Bertha Brook and along it to Bertha Lake.

The rocks along the trail are progressively younger toward Bertha Lake because they 'dip' or slope generally to the southwestward. On the shore of the main Waterton Lake the Waterton Formation is exposed in two main slices, separated by more or less parallel 'faults' or breaks. As you travel upward along the trail toward the outlet of Bertha Lake, more fault slices expose the buff dolomites of the overlying Altyn Formation. Surrounding the steep-walled valley in which Bertha Lake itself lies are green argillites of the Appekunny Formation; the rock wall at the southwestern end is carved in the red beds of the Grinnell Formation and the grey limestones and dolomites of the Siyeh Formation.

The depression in which Bertha Lake is located was carved by glaciers and the rock wall at its head is a more or less bowl-shaped 'cirque'. These bowls are commonly formed by glaciers at the headwalls of valleys and seem to be the result of ice and snow moving in toward the centre of the valley from all sides. When the glacier that formed this cirque had almost disappeared, the scoured-out upper end of the valley filled to the line of the lowest outlet to form Bertha Lake; the overflow formed Bertha Brook.

(4) Trail to Crypt Lake

From the boat-landing near the Warden's station, across the main Waterton Lake from the town and south about



Crypt Lake lies in a great glacial bowl or 'cirque' in the upper left corner of this picture. Its outlet crosses through and under a patch of boulders and then forms this slim waterfall over a great cliff as it begins its 2,400-foot fall to the level of the main Waterton Lake.



The trail to Crypt Lake passes through a rock tunnel cut through a spur in the cliff face just below the bowl in which the lake itself lies. Here, looking northeast toward the kitchen shelter in the woods, the trail winds along a great scree slope covered with buff slabs of rock of the Altyn Formation mixed with red and grey dolomite of the Waterton Formation.

a mile, a trail leads up over the hump of land, down into the valley of Hell Roaring Creek, and along the creek for about 5 miles to Crypt Lake. Where the trail from the Warden's cabin first leads back over the hill there is one place that offers an excellent view northward to the townsite of Waterton Park (see photo on page 51). From here the bulk of Mount Crandell to the right or north and the lower spur of Bertha Peak to the west or left frame the valley of Cameron Creek and the delta at its mouth on which the townsite is built. From this high point the trail leads around the slopes and then down into the valley of Hell Roaring Creek, some distance above its mouth.

Farther along, the trail passes two sets of waterfalls in Hell Roaring Creek. The cliffs over which they fall were apparently carved by the glacial ice that once filled this valley, steepening its walls and here and there filling its



In mid-June, Crypt Lake at an elevation of 6,500 feet above sea-level, is still surrounded by last winter's snows and still partly covered with ice.

Just below the falls
near the outlet
of Crypt Lake,
Hell Roaring Creek
expands into this
quiet pond on
the valley flat.
The tremendous
rock wall with the
long scree slopes
below it consists
mostly of rocks
of the Altyn
Formation.



bottom with 'glacial outwash' at the time of its melting. At the first or lower falls, the stream has undercut a mass of limestone by removing the softer rock and has cut back into the original cliff. The Mount Crandell thrust, which lies just below the limestone, is one of the great fault surfaces on which huge slices of rock have moved up one over another to make the complex rock structure characteristic of this whole area.

The upper waterfall tumbles over a cliff that at one time must have been the headwall of a glacier, because it forms the back of a more or less bowl-shaped feature (a cirque).

Immediately above it another great cirque has been carved into the rocks of the Appekunny Formation by glacial ice. It is in this bowl that Crypt Lake now lies, in a spectacular setting of great grey cliffs and long graceful 'scree' slopes leading directly into the water.

The upper valley
of Hell Roaring
Creek looking
downstream shows
one of the typical
glacial valleys
in Waterton Lakes
National Park.

The steep but
flaring sides
covered in 'scree'
on the lower
slopes, flatten out
to a wide valley
bottom. Occasional
sharply marked
steps show where
great icefalls once
were.



(5) Trip along Waterton Lakes (Southern Lake)

As you pull away from the landing and turn directly southward into the main reach of the lake you may notice the low ground on which the townsite of Waterton Park is built. This is the delta that formed from the sand, gravel and boulders which were carried down Cameron Creek by the glacial meltwaters and were spread around by waves in the lake. As you travel away from the delta, its flat fan-like shape becomes clearer. A long, low point on the east side of the lake opposite the townsite is made of white, grey and brownish yellow rock units of the Altyn Formation. They dip to the northeast at about 20 degrees so that from this part of the lake you are looking at the upturned edges of the strata.

As you pass down the lake you will notice that brooks have built deltas which stick out into the lake at the mouth of each major valley as low flats with rounded outlines. Here and there, such as at the mouth of Hell Roaring Creek, the white of waterfalls may be seen. These falls, at the edge of the main lake, were all formed when the small tributary streams reoccupied preglacial drainage valleys only to find that the main valley system had been deepened very considerably by the ice.

A little more than halfway down the lake you cross the International Boundary, marked by posts on the shores of the lake and lines cut through the woods on each side. This is the 49th parallel of latitude which, from near Vancouver all the way to Lake of the Woods east of Winnipeg, forms the boundary between Canada and the United States. A view to the south from this position on



From the east side of the main Waterton Lake, not far above the trail to Hell Roaring Creek and Crypt Lake, this view northwestward takes in Mount Crandell on the right and the valley of Cameron Creek just to the left of centre. The townsite of Waterton Park is on a delta of Cameron Creek — a delta that was probably built at a time when large glaciers still occupied parts of the upper valley of the creek and supplied large quantities of debris.

the lake shows the superb conical peak of Mount Cleveland on the left, with its flat-lying sedimentary rocks and its conspicuous 'sill'—a layer of igneous rock that moved into the sedimentary pile as a hot liquid under great pressure. You can clearly see where the rocks adjacent to the sill have been bleached by the heat and igneous juices from the molten mass.

From the middle of the lake you can see how the horizontal layering in Gothaunt Mountain and Mount Cleveland contrasts with the sloping layers of Mount Richards and others on the west side of the lake. The horizontal layering in Citadel Mountain has produced great spikes and towers where erosion has cut into the two sides of its eastern spur, making a very dramatic profile.

At any place along the lake it is interesting to think of this great mass of mountains as the result of a thousand million years of geological history. The layering in the peaks began on the floor of a shallow sea where muds, silts and sands were being deposited. Ancient storms or floods in rivers caused changes in the kinds of sediments being spread out over the sea bottom, and brought about the layering. After deep burial under succeeding sediments, the whole pile turned to solid rocks; but it preserved evidence of its sedimentary ancestry in the form of layering (bedding or stratification), ripple marks made by waves and currents, and, in some places, the separation of pebbles, sand and mud in a way that can only be accomplished by water.

After all this the layered rocks were injected by thin sheets of molten rock that altered the adjacent rocks, as in Mount

Cleveland. Then the whole complex was broken by great faults into blocks and sheets, and these in turn pushed together so that some rode up over others for distances of several miles. The final result of the folding and breaking and the uplift and overriding was an enormous, complicated mass of rock structures, into which rivers and glaciers cut deep valleys and depressions. The mountains become even more awe-inspiring when you see them in this way.

(6) Trail from Waterton Lakes to Cameron Lake via Alderson and Carthew Lakes

From near Cameron Falls in Waterton Park townsite a trail leads up the valley of Cameron Creek to its tributary, Carthew Creek, along this creek to its headwaters in Alderson and Carthew Lakes, and over the summit and down the other side to Cameron Lake. This trail provides superb views of many of the interesting parts of Waterton Lakes National Park; it traverses all the botanical zones—from heavy forests of great trees at the lower levels, through the stunted evergreens and low bushes near the level where tree growth stops, to the bare hills where only lichens, mosses and alpine flowers grow—and also provides a complete survey of the rock types in the park.

From the Waterton Park end, the trail leads rapidly uphill, then swings around to parallel the lower canyon of Cameron Creek above the waterfalls. It then turns westward up the steep valley of Carthew Brook and crosses, successively, units of the Waterton, the Altyn, the Appekunny, the Grinnell, and the Siyeh Formations, before



Horse and rider stop on the steep slope above Alderson Lake on the trail to Carthew Lakes. Masses of rock rubble have tumbled from the weathering cliffs in the background to form the 'scree' slopes that extend for hundreds of feet above the water and on down to the very bottom of the lake.

reaching Alderson Lake. Very little rock is exposed on the trail itself but cliffs of these formations may be seen in the wall of the valley opposite.

Great cliffs of the Grinnell Formation, overlain by the Siyeh Formation, form the west side of the Carthew Creek valley about $\frac{3}{4}$ mile from Alderson Lake. One great sill of rock, which at one time was molten and squeezed its way in between the sedimentary layers, is visible in this cliff as a dark band with bleached edges paralleling the sedimentary layering.

Alderson Lake itself is like so many of the other lakes in the upper levels of Waterton Lakes National Park because it lies in a great bowl-shaped depression or cirque. These empty cirques tell of the waning stages of a glaciation that at one time covered all of Canada and a considerable strip along the northern United States, with a vast ice-cap. As the climate warmed up and the ice-cap began to disappear, remnants stayed as local glaciers that carved deeply into the mountains, scouring out valleys and gouging out such cirques.

At Alderson Lake the cliffs are principally cut in sedimentary rocks of the Siyeh Formation but include dark layers of igneous rock—rock which at one time was molten—whose heat and juices have bleached the adjacent rocks. Examples can be clearly seen in the headwall and the cliffs slightly to the left as you look at Alderson Lake from the picnic site.

From Alderson Lake the trail leads steeply upward for nearly a thousand feet to the level of the Carthew Lakes.

Part way up this trail the view back into Alderson Lake shows very clearly what a tremendous bowl of mountains surrounds this tiny body of water. From some parts of this trail the view northeastward provides glimpses of the great plains beyond the edge of the mountains in the far distance.

When you reach the lower of the Carthew Lakes the trail swings northward along a great scree slope on which you may find a variety of rocks fallen from the cliffs above. These include a selection of limestones and dolomites, various red and green argillites, and large blocks of dark purplish green basalt. In some places this basalt is full of round holes which have become filled with light-coloured minerals by percolating groundwaters. The holes were bubbles of gas in the rock when it was molten and were trapped in the rock when it solidified. This igneous basaltic rock forms a layer which generally parallels the layers of other rocks and can be traced for many miles across the countryside by following the outcrop pattern.

The upper of the Carthew Lakes lies in a bowl of cliffs and scree slopes dominated by fragments of the reddish Kintla Formation. Around the outlet you may find large slabs of clearly ripple-marked and well-bedded sandstones. On some of the ledges in this neighbourhood unusual displays of lichens are also in abundance. You may wonder how these plants can exist with so very little soil, and in such a very harsh climate.

Beyond the Carthew Lakes the trail leads over treeless country where the red and pink argillites and quartzites



The walking trail between Alderson Lake and the lower Carthew Lake climbs steeply up the hillside in the foreground. The glacially carved bowl in which Alderson Lake lies is cut into rocks of the Siyeh Formation. The sedimentary layering of these rocks 'dips' or slopes gently down and to the right, interrupted here and there by breaks that dip steeply down and to the left. One of these breaks accounts for the great gully at the right with the 'scree' slope below it, and similar but less strongly developed features farther to the left.

In this view across the lower Carthew Lake the gently dipping rocks belong to the Siyeh Formation. Large blocks of basalt and fragments of rocks of the Sheppard and Kintla Formations, which overlie the Siyeh Formation, litter the great 'scree' and rubble slope to the left of centre. The trail to Alderson Lake crosses this slope.



A brisk wind whips the upper Carthew Lake where, in mid-June, large patches of last winter's snow are still on the scree slopes. The outlet of the lake has breeched the ripple-marked silty sandstones and argillites dipping away from the foreground. The scree slopes in the background are unusual in their reddish colour and have come largely from red argillites of the Kintla Formation in the upper slopes.

of the Kintla Formation colour the hills. On the western end of the trail are superb views of Cameron Lake and the mountains along the continental divide which separates Alberta from British Columbia.

AKAMINA HIGHWAY TO CAMERON LAKE

7) Viewpoint over Northern End of Townsite

The townsite of Waterton Park lies below in a fan-shaped delta made by Cameron Creek at a time when its volume was several times greater than now because of a vast outpouring of water from rapidly melting glaciers. The materials in the delta itself probably came from erosion of the hills and valleys to the west and northwest of the townsite. Several other similar deltas are to be found along the length of the main Waterton Lake at the mouths of the major valleys there. Northeastward from this viewpoint the rolling plains east of the edge of the mountains lead off toward the horizon.

Directly east the complicated mass of Vimy Peak dominates the view. Near its top the yellowish brown rocks of the Altyn Formation have a sort of spiky appearance as they gradually erode away. A light-coloured band that separates these rocks from green-grey and red argillites of the Appekunny Formation below marks the presence of a great thrust surface over which the pale yellow-brown rocks on top have slid up and over the younger Appekunny rocks. This particular surface, called the "Mount Crandell thrust", may be traced over a very large part of Waterton Lakes National Park. If you examine the face of the moun-

tain carefully you will be able to see that the Mount Crandell thrust surface cuts gradually across the edges of the beds underneath it. At the base of the mountain a massive grey-weathering bed is traceable from where it is first visible on the right, across the foot of the mountain and on into the long low point directly opposite the townsite. Below it in the point, brown, yellow and grey beds—the same Altyn Formation as in the top of Vimy Peak—make a colourful outcrop. The same massive grey dolomites are visible again in the point and bank below the hotel on the west shore of the lake at the narrows.

From this viewpoint the chalet-like hotel sits conspicuously on a terrace of outwash glacial materials that seem to have been plastered onto the resistant rock rib below. The rocks of the long low point just across the narrows dip or slope generally to the northeast and include units of the Waterton Formation at the lowest levels giving way to younger rocks of the Altyn Formation above and on the tip of the point.

Behind you on this viewpoint a long road-cut reveals brown-weathering sandy dolomites with some grey shaly layers and occasional red beds. If you look into some of these layers you will see that they are very finely stratified or layered, representing sea-bottom accumulations of fine dolomitic mud. They belong to the lower part of the Altyn Formation. As you go along the cut you may notice that the steep dips characteristic of most of the outcrop are suddenly interrupted at a place where the rocks are crushed and broken over a width of a few inches. Beyond this the sedimentary layering seems to be folded into curving units



Vimy Peak is a mountain of unusually complicated structure opposite the town of Waterton Park. The great mass of grey, green and purplish rocks into which the mountain is carved consists of a number of sheets of rocks which have been thrust up one on top of another. Several breaks or thrust planes can be seen in the face of the mountain where they show as discontinuities. The light grey zone below the uppermost cliffs marks the Mount Crandell thrust, the most extensive of the visible ones.



A road-cut in the Akamina Highway, directly above the townsite of Waterton Park, shows the freshly exposed steeply dipping bedded rocks. A little farther along the road a clearly marked fault shows where one group of rocks has been pushed over another, a structure which is very common in the mountains of this area.

which are cut off abruptly by the same zone. This is a thrust fault and marks a place where the rocks have been broken and different masses been pushed over one another in adjustment to great stresses in the earth.

In the next mile or so along this road, viewpoints and curves in the road provide several views down into the gorge of Cameron Creek. The gorge, cut mostly in yellow-brown dolomite of the lower Altyn Formation, shows how very slow solution of the rock, combined with abrasion by the passage of boulders and sand over the bottom, gradually wears away the land and, after thousands of years, produces considerable change in the landscape.

(8) Falls on Cameron Creek and Oil City

A tumbling white waterfall is made where Cameron Creek drops over layers of grey, gritty limestone and sandy beds. Some of these show a marked sheety breaking and others have nicely ripple-marked surfaces where waves long ago disturbed fine muds on the bottom of the sea.

About a third of a mile farther along toward Cameron Lake is the "Site of Alberta's First Oil Discovery", a place called "Oil City". The only remains of the "city" are a few pieces of rusted wire rope, bits and pieces of old iron and wood, and two pieces of well-casing sticking out of the ground. One of these has a railing around it and a piece of drill stem stuck firmly in the hole.

The rocks exposed around here are of Precambrian age, and more than a billion years old, and nowhere in the world is oil found in any quantity in such ancient rocks.



"Oil City" lies between the road and Cameron Creek on the Akamina Highway. Instead of the above inscription, this place is probably better remembered as "the site of the first well drilled for oil in Alberta".

Oil, seemingly, is distilled by natural processes from the remains of living things; but from all the evidence at hand, living things were not very abundant in Precambrian times. Thus the rocks at the surface around these oil wells are apparently too old to contain oil. Studies of the structure of the rocks, however, show that these old rocks do occur in great thrust sheets which were broken from their original places of deposition during the folding and faulting of the mountain region and pushed up over younger rocks for distances of many miles. This means that holes drilled

down through the blanket of older rocks would penetrate younger rocks beneath the bottom thrust plane and thus would have some possibility of penetrating oil-bearing rocks. It is possible too that a little oil leaked out of the younger rocks below and moved into the older rocks above.

The long ridge to the southwest (or left as you travel toward Cameron Lake) is the flank of Buchanan Ridge. Here and there along its sides you will see shallow basins scooped out of its sides. These are partly developed cirques cut by patches of glacial ice when the climate was a little colder than it is now. Almost all of them have small brooks coming out of them and some still have residual banks of snow very late into the summer.

(9) Cameron Lake

Cameron Lake is set in a glacially carved and dammed basin right up against the continental divide, that is the line that separates the drainage flowing eastward from that flowing westward. Eastward drainage goes into the Waterton Lakes and thence northeastward into Saskatchewan River toward Hudson Bay; water flows westward through Akamina Brook and Kintla Creek and eventually into the Pacific Ocean via Columbia River. Cameron Lake has a very high rugged back wall and a much smoother and low outlet area, as do many other lakes near the divides in this area. The basins in which these lakes lie were all carved by glaciers which tended to cut bowl-shaped depressions with very steep to vertical headwalls, resulting from the movement of the snow and ice toward their centres. At their ends, these small, local glaciers would

drop the boulders, gravel and sand which they had picked up higher in their courses. Commonly, when the ice disappeared a lake formed in the partly carved and partly dammed up basin. If you walk around Cameron Lake to the outlet brook you will see that it starts its northeastward flow over a series of boulders and broken rock marking the glacial dam.

It is interesting to note that the high back wall at the south end of Cameron Lake is in the United States, with the International Boundary cutting across the southern tip of the lake. The south-trending ridge to the right or west of Cameron Lake is the boundary between the Province of Alberta and the Province of British Columbia; at a three-way boundary point it intersects the International Boundary.

About half a mile northwest of the end of the road on the shore of Cameron Lake, Akamina Pass, 5,835 feet high and less than 400 feet above the water of Cameron Lake, provides an easy access route into the southeastern corner of British Columbia. Directly east or to the left as you face along the length of Cameron Lake the trail to the Carthew Lakes zig-zags up the steep slopes and is visible in one or two places. The bright shining patches to the northeast are on the lower slopes of Mount Carthew. The overall view in this direction shows grey-green layers within the generally grey rocks, and occasional spills of bright red debris down the slopes from outcrops of red silty shales. The reddish areas are mostly scree from outcrops of the Kintla Formation, the youngest Precambrian rocks in the area.



Cameron Lake is set in a rock-rimmed bowl in the southwestern corner of Waterton Lakes National Park. Mount Custer, the peak at the left, and the glacially steepened wall of horizontally bedded rocks lie beyond the International Boundary in the United States; almost all of the lake itself however, lies on the Canadian side.

THE ROAD TO RED ROCK CANYON

(10) Junction of Red Rock Canyon Road and Main Road

From the road junction the mass of Vimy Peak looms to the southeast, with its flat-lying rocks in the upper layers and its seemingly crumpled grey, green and reddish rocks below. A broken zone of light brown rock debris marks the position across the mountain face of the Mount Crandell thrust, one of the great surfaces of breakage and movement in this area. You can see from here that the red beds just below the surface and to the left are cut out gradually as you look more to the right. At the bottom of the mountain and covered with debris and vegetation, another great fault, the Lewis thrust, marks the base of the entire sheet of crumpled and broken older rocks lying on top of the younger rocks of the plains.

Swing your eyes to the right and see the low, light grey dolomite ridge between the main body of the Waterton Lakes, which runs generally north and south, and the northern arm, which runs more east-west. This ridge must have made sort of a threshold for the glaciers filling the main Waterton valley. Above the ridge in the distance you can see the jagged spikes of Citadel Mountain in Montana, and next to it the bulk of Mount Campbell with strata sloping to the right.

Still farther to the right looms Mount Richards, with greyish rocks in the lower part interrupted by a layer of limestone that sticks out and clearly shows a general dip of the strata away from you. The great rock wall which extends from Mount Richards to Mount Alderson can be seen to be

layered even from here. The snowslide-scarred slopes of Bertha Peak rise above and to the right of the chalet. Light-coloured limestones and dolomites of the nearer peak to the right change along fault lines to darker greys and reds to the west of you in the slopes of Mount Crandell.

Straight out the Red Rock Canyon Road the sharp peak is Mount Galwey, with various ridges and spurs of Bellevue Hill to the right. Mount Galwey has gentle lower slopes but a horizontally layered top part gives rise to spiky forms from weathering. All these mountains are cut into a complicated mass of rocks which began as horizontal layers but have been broken along great thrust planes, with one sheet of rocks riding up over another and the whole mass being pushed up over the young rocks of the great plains to the east. The road junction here lies within a few hundred feet of the Lewis thrust which is the bottommost of the major thrust surfaces. It thus separates the whole pile of older rocks above and to the west from the younger rocks below and to the east. The terrace just ahead on the Red Rock Canyon Road appears to be glacial outwash; its flat top is strewn with round boulders and cobbles.

(11) Middle of Long Straight Stretch

Straight ahead along the road the lower flanks of Bellevue Hill show conspicuous sedimentary layering in red, grey and green-grey. Scree slopes are covered with grass in the lower parts so appear to be not actively receiving debris from above. Here and there large boulders, however, have rolled down into the fields beyond the scree slope in some places. Northwestward up the valley of Blakiston Brook



The rushing waters of Blakiston Brook are gradually eroding the base of this high bank of glacial outwash. Gullies with fans of loose debris alternate with nearly vertical projecting ribs just west of the main road, about a mile north along the Red Rock Canyon Road.



The road to Red Rock Canyon passes along the valley of Blakiston Brook. This view, about halfway between Red Rock Canyon and the junction with the main park road, is dominated by the mass of Mount Blakiston, the highest in the park at 9,600 feet above sea-level. The bare rocky slopes on top with scree slopes below leading downward into heavily wooded valleys are typical of the mountains in Waterton Lakes National Park.

the several peaks of Mount Blakiston show the horizontal layering of rocks. One igneous sill is visible even from here with the bleached adjacent rocks both above and below it. Just across the fields from here Blakiston Brook is cutting into a thick bank of glacial gravels to make an unusual shoulder and gully pattern.

It is interesting to note that the slopes of Mount Crandell, to the southwest across Blakiston Brook, show a faint banding of the vegetation. This is because the various rock layers that stick out in those slopes produce slightly different growing conditions in terms of soil and drainage, and these affect the kinds of plants which grow best there.

(12) Flat Below Red Outcrops to the Right or North

Very red rocks with grey-green and white layers crop out in several places along the road. These are red argillites of the Appekunny Formation. Far back and high above the road here Mount Galwey shows steep cliffs at its summit above gentler lower slopes. Southward and southeastward from here the mass of Crandell Peak is a complicated mass of folded rocks, snowslide scars, some deep gullies, and a few runnels made by rock fragments.

Ahead, the bulk of Mount Blakiston, the highest mountain in Waterton Lakes National Park at 9,600 feet above sea-level, contrasts with the much more gently rounded outline of Ruby Peak to the left with its grasslands and tree slopes alternating with limestone cliffs and struts.

(13) Copper Mine Creek

This creek gets its name from traces of copper found along its banks some time ago in a sill of igneous rock in the Grinnell Formation. A view to the south from here shows a low pass that leads through the Crandell Lake valley into the upper valley of Cameron Creek and the Akamina Highway to Cameron Lake. The various peaks of Buchanan Ridge fill the skyline through the gap.

(14) Straight Stretch on Valley Flat

The valley flat here is mostly on till-boulders and sand washed from the nearby mountains by streams in recent times and large quantities of debris flushed out from the hills in the meltwaters from glaciers. Above and to the left the peak on Mount Blakiston shows an indistinct sill of igneous rock which is visible because it is slightly darker than its surroundings and because it is broken into vertical spikes by weathering and jointing it in. Red beds and some slopes from them show here and there in the lower slopes. To the northwest or a little to the left as you face along the road toward Red Rock Canyon the sloping peak of Mount Anderson shows more or less horizontal sedimentary layering with one very well marked sill of igneous rock. The bleaching on each side of this layer of what was once hot molten rock is quite well shown.

The smooth rounded outline of the north slopes of Mount Crandell is visible back and to the southeast. Dead wood along the road toward Red Rock Canyon a variety of peaks marks the skyline with one exceptional one in that range having a very smooth outline.

(15) Red Rock Canyon

Red Rock Canyon has been cut into soft, red argillites of the Grinnell Formation by the small brook flowing off the high mountains to the northeast. Nearly horizontal layering in the rock is marked by slight variations in the red color and by sharply contrasting pale grey-green and yellow-green layers. The pale grey-green occurs also in spots and irregular patches. These light patches all represent places where the iron compound in the rock has been changed in color.

position because of the presence of some other chemical substance. Ordinarily it is in the same form as the iron in reddish iron rust, but where it comes in contact with some organic matter or 'reducing agent' it changes to a different composition which has this pale yellow-green or grey-green colour. Along the canyon walls some of the grey layers appear to be a little harder than the reddish rocks in which they occur, and they stick out as ledges.

You may note large boulders in the bottom of the canyon. They probably began their history as part of the load of the glaciers once covering this area. After the ice melted the boulders were deposited and have since been brought downstream by running water. Among the boulders you will find quite a few dark, dense basalt and gabbro ones which have come from the sills of basalt and gabbro higher up in the mountains—as in Anderson Peak and Mount Blakiston. This rock was at one time molten and was squeezed in between the sedimentary layers at various levels in the mountains. In addition to these dark basalts, boulders and cobbles of red and grey limestone with some grey sandstone are also found in the brook bed.

Along the brook you may notice that smooth, nearly vertical faces seem to intersect the canyon wall. These are joints made when the rock fractured from large stresses, perhaps set up during the making of the mountains themselves. On the right side of the canyon going upstream, one of the light-coloured layers shows fairly well developed ripple marks on one surface and here and there some shrinkage cracks—the kind formed when wet sediments dry out at low tide or at a time of year when streams are low.



The bulk of Mount Blakiston looms over the bridge area at Red Rock Canyon. The sharp jagged peaks are complemented in their lower slopes by extensive 'scree'. The wooded slopes in the lower parts are scarred by light green areas which are low bushes growing where snow-slides have cleaned out larger darker trees.

Just above the bridge some parts of the canyon bottom are quite well rounded and appeared to have been parts of 'potholes'—made when hard boulders are whirled round and round by the moving water and gradually bore their way into the softer rock beneath. A few hundred feet above the bridge the canyon shallows rapidly and gradually becomes a normal brook valley.



Red Rock Canyon is cut in reddish siltstones. As in most red formations which owe their colour to iron oxide, patches and layers of pale green rocks are common. These represent places where the iron is in a different state and exists as a colourless to pale green compound.

The view from the bridge area shows a beautiful vista of mountains typical of Waterton Lakes National Park. Looking downstream or to the southwest, Blakiston's mass with

several peaks dominates the skyline. Its flanks are streaked with pale green stripes of annual vegetation and low bushes which grow where snowslides have removed the larger and darker trees. In one of these places the waterfalls from a small brook make several white strips. Ice-eroded cirque walls are visible in two places.

To the right or north of Mount Blakiston the long valley of Blakiston Brook leads westward toward distant peaks on the continental divide which marks the boundary between Alberta and British Columbia. On its north side (to the right) are the red slopes leading to the sharp spike of Anderson Peak, cut in grey and brown rocks. One prominent sill of rock, once molten, shows strong bleaching of the invaded rocks both above and below it. Northwestward up the valley of Bauerman Brook and beyond it are the spurs and peaks of Cloudy Ridge.

(16) Road and Trail Northwest from Red Rock Canyon

Riding and walking trails and a fire road, which may be driven only with a permit from the park authorities, lead northwestward from Red Rock Canyon Warden's Station along the valley of Bauerman Brook to the northwest corner of the park. This area provides a changing scene of mountains and valleys typical of this part of the Rocky Mountains.

Walking trails lead to Goat Lake, Lost Lakes and Twin Lakes, which each lie in a 'cirque'—a glacially carved bowl with steep headwalls and much less rugged outlet areas. The high ridge back of Twin Lakes and Lost Lakes is the con-



Riders head westward along the trail to Twin Lakes and Sage Pass in the northwestern part of Waterton Lakes National Park. The crest of the steep rock wall in the background lies close to the continental divide, the boundary between Alberta in the foreground and British Columbia beyond the ridge.

tinental divide. Back of Goat Lake, however, a more local divide forms part of the irregular northern boundary of the park.

(17) Trail from Red Rock Canyon Westward Along Blakiston Brook

A walking trail leaves the Red Rock Canyon area just beyond the bridge and leads westward along the northern bank of Blakiston Brook for several miles. About half a mile from the bridge it passes Blakiston Falls. As in all waterfalls where water plunges over rocky layers into a pool the low rumble of Blakiston Falls can be heard for quite some distance.



Small lakes are very common near the dividing ridges in the headwaters of streams in heavily glaciated mountains. The northern Twin Lake lies at the foot of this great cliff at the head of Bauerman Brook.

From near the continental divide at the end of this trail, side trails lead southward to Lone Lake and northward to Twin Lakes.

VIEWPOINTS ALONG HIGHWAY 6

(18) Northern Entry on Road from Pincher Creek

Rolling grasslands in view here are only a fragment of those of the great plains which stretch eastward for thousands of miles. The sharply marked front of the Rocky Mountains crosses diagonally in a southeast-northwest trend. Along the mountain front glacial debris and waste, brought down by streams off the hills, help to obscure the sharpness of the geological boundary between the old rocks, now found in the mountains, and the younger rocks underlying the plains. The boundary is actually a great fault, called the "Lewis thrust", and is a surface along which a huge series of slices of rocks has been pushed up over the rocks to the east. Erosion into the thrust-up rock mass has produced the mountains we now see and has exposed old rocks at the surface.

To the northeast the low hills with rubbly rock and scree slopes form Lakeview Ridge. Beyond it and just a little to the left the horizontally terraced slopes form Mount Dungarvan. Through the bowl straight west from here the horizontally layered slopes of Mount Galwey cradle the headwaters of Galwey Creek in a great number of small runnels and valleys.

As you swing your gaze gradually southward the several spurs of Bellevue Hill are followed by the smooth outlines of Mount Crandell and beyond that the rugged mountains,

many miles to the south, on the right or west side of Waterton Lakes. Looking still farther to the left past the gap of the Waterton Lakes the patterned slopes of Vimy Peak give way eastward to the bare brown front of Sofa Mountain, then the sharp edge of the mountains and the grasslands of the gently rolling western edge of the plains.

From this stopping place one small peak, some 20 miles to the southeast, seems isolated from the main front of the mountains. It is Chief Mountain in Montana and is an outlier or remnant of a slice of rocks that has been pushed out over the younger rocks underlying the plains. Erosion since has removed great quantities of the overthrust rocks to leave now this remnant sitting by itself.

(19) Viewpoint on Big Bend

This stop provides an excellent view westward over the gently rolling lands to the edge of the mountains and the gap made by the Waterton Lakes. The brown slopes of Sofa Mountain rise to the south and southwest. To the right as you look at it, Vimy Peak with its complicated rock structures forms the southern entrance to the Waterton Lakes valley. As you look farther to the northwest, directly over the end of the main lake, the valley of Blakiston Brook stretches off into the distance. The Red Rock Canyon road follows this valley, with trails leading from its end to the continental divide and the boundaries of the park. On its right the low flank in front is Bellevue Hill and the spike with a patch of red scree before it is Mount Galwey, with the high ridge of Mount Dungarvan to its right. Directly up

the valley is Anderson Peak which lies fairly close to Red Rock Canyon. To the left of the valley, part of the eastern peaks of Mount Blakiston show over and behind the mass of Mount Crandell whose front end and top show great folds making a giant "S" pattern. The light grey slope on the left side of Mount Crandell as you look at it from here makes the light-coloured hill that is conspicuous in Waterton Park townsite. A little to the left of this, a dark wooded slope with light green stripes made by snowslides is part of Bertha Peak, and the high peak just to the left of it is Mount Alderson.

The rocks under the rolling hills in this part of the park are of Cretaceous age, that is they were laid down as sand, gravel and mud approximately 100 million years ago. A few low outcrops in road-cuts and brooks in the neighbourhood show that these rocks are cut by dozens of breaks or faults which dip southwestward. Movement along these faults, however, has not been very great so that the same rock unit is not displaced very far from block to block. When we come to the abrupt edge of the mountains, however, we find that very much older rocks in the mountains themselves have been thrust up over a fault surface that cuts at a shallow angle diagonally across the younger rocks with a dip to the west. Along this surface (the Lewis thrust), a tremendous mass of rocks has been thrust up and over the younger rocks to the east. In some places erosion has removed much of the overlying sheet so that the edge of the older rock is irregular and pieces of the thrust sheet are even left isolated as in Chief Mountain, nearby in Montana. Within the mass of older rocks, out of which the Rocky Mountains in this sec-



A general view of the valley occupied by the lower Waterton Lakes, looking southwestward from the big curve of Highway 6 about 2½ miles southeast of the park entrance. Vimy Peak is on the left and the point of Bertha Peak is a little to the right of centre; other peaks to the southwest of the village of Waterton Park are partly shrouded in rain showers, with their tops in the clouds.

tion have been carved, numerous other thrust surfaces along which movement has taken place have contributed to the enormous complexity of the structure within the mountains.

(20) Stop Just East of Warden's Station

Chief Mountain, an erosional remnant of part of a great sheet of older rocks thrust out onto the younger rocks of the plains, shows beautifully from this area, some 15 miles away. Sofa Mountain looms large to the southwest. Its grassy lower slopes are mostly developed on scree and material that has fallen from above and has now become stable. Gullies here and there cut deeply into its flanks and preserve patches of snow until very late in the summer. From the hilltops near here the long line of the front of the Rocky Mountains can be seen stretching away to the northwestward for some 45 miles.

(21) Belly River Crossing

Belly River drains a large sector of Glacier National Park along the northern edge of the United States, then flows northward through Alberta, picking up the drainage from the eastern flank of the southern Canadian Rockies. It receives the water from Waterton River and eventually empties into South Saskatchewan River.

Here at the river crossing a view up stream looks deep into the mountains of northern Montana. In the river bottom, deposits of sand and gravel are in constant change as the river gathers sediment in some places and deposits it in others.



Belly River flows northward from the State of Montana and crosses the southeastern part of Waterton Lakes National Park. The part of the river shown here is upstream from the bridge on Highway 6, looking southwest beyond the edge of the rolling country to the mountains beyond.

(22) Southeastern Gate at United States Border

Highway 6 at this point is almost in the southeasternmost corner of Waterton Lakes National Park. For the 4 miles between the border and the Belly River crossing the road follows along the eastern side of the valley of Belly River.



The narrows on Waterton Lakes are formed by a strut of dolomites of the Altyn Formation. On the near side the rocks are covered with a thick blanket of glacial outwash, forming the terrace on which the hotel stands. The lower slopes of Vimy Peak are in the upper right corner.



Chief Mountain, Montana, is visible from several places in the southeastern section of the park along Highway 6. It is an unusually fine example of an 'outlier'—a patch of rocks that was once part of a great thrust sheet lying on top of other rocks below the fault surface and now almost entirely removed by erosion. This view, from a point a few miles south of the border, clearly gives the impression of an erosional remnant.

Occasional glimpses of the mountains to the west and the wooded valley in between show us the two main divisions of the landscape in the park. The mountains themselves are carved into an enormous mass of very old "Precambrian" rocks, about one billion years old. These have been broken and faulted, with one block riding up over another and then the whole mass being deeply dissected by glacial and stream erosion. The rolling hills in the eastern section of the park where this part of the road is situated are underlain

by very much younger, sedimentary rocks—"Cretaceous" in age, about 100 million years old. These are broken here and there by faults along which only a small amount of movement has taken place, so that the disturbance in the rocks has not been great. The plains extend eastward from these rolling foothills for hundreds of miles—a vast area of flat and undisturbed rocks.

EPILOGUE

Driving or walking through the valleys and mountains of Waterton Lakes National Park, or just reminiscing about summer experiences there, you derive a more meaningful sense of beauty from the scenery if you think of its beginnings. A thousand million years ago it was covered by that ancient sea which spread slowly over the sinking land. The layered rocks now found in the highest peaks began in that ancient sea as layers of mud, silt and sand. Where hikers and horses carefully pick their way along the scree slopes above the highest growth of trees, waves once stirred the sea bottom and made ripple marks you can see even now on some of the rock surfaces. Where peaceful glens and deep forests echo the sounds of rushing brooks there once moved great glaciers, carving and scouring the ancient rocks beneath them. Campers now cook their evening meals and pound in their tent pegs where a swift torrent of floodwaters flowed from the melting glaciers higher up the valley, carrying masses of sand and gravel which spread out to make the delta the town now stands on.

In the peace of the evening or early morning the calm waters of the Waterton Lakes reflect great mountains that in earlier times were thrust up thousands of feet, then deeply incised by ancient rivers. Where boats now cruise on the lakes a great glacier, drawing its icy substance from all the surrounding valleys, gouged out an old river valley, deepening and steepening it.

And, perhaps most intriguing of all, geological processes—the adjustment of great masses of the earth's crust, the slow crumbling of the rocks and the wearing away of the land—are still going on all around.

For more information on the geology of Waterton Lakes National Park see the following publications.

A Guide to Geology for Visitors in Canada's National Parks, by D. M. Baird. Published by the National Parks Branch, Department of Northern Affairs and National Resources. Available from the Queen's Printer, Ottawa, or from any of the National Parks. This pocket-size book describes the general principles of geology with special references to the National Parks of Canada, written in layman's language (153 pages, 48 illustrations).

Waterton, Alberta, by R. J. W. Douglas. Preliminary Paper 52-10 of the Geological Survey of Canada (1952). Available from the Queen's Printer or the Geological Survey of Canada, Ottawa. The geology of most of the area of Waterton Lakes National Park and part of the adjacent plains is mapped and described on a technical level.

Geology of the North American Cordillera at the Forty-ninth Parallel, by R. A. Daly. Memoir 38 of the Geological Survey of Canada (1912). Pioneer account of the geology along the southern boundary of the park and a reminder of the days when travel in these mountainous areas was still a great adventure.

Particular questions of a geological nature concerning Waterton Lakes National Park should be addressed to the Director, Geological Survey of Canada, Ottawa, or to the office of the Geological Survey in Calgary or Vancouver.

For information on all other matters concerning the park, write to the Director, National Parks Branch, Department of Northern Affairs and National Resources, Ottawa.

INDEX

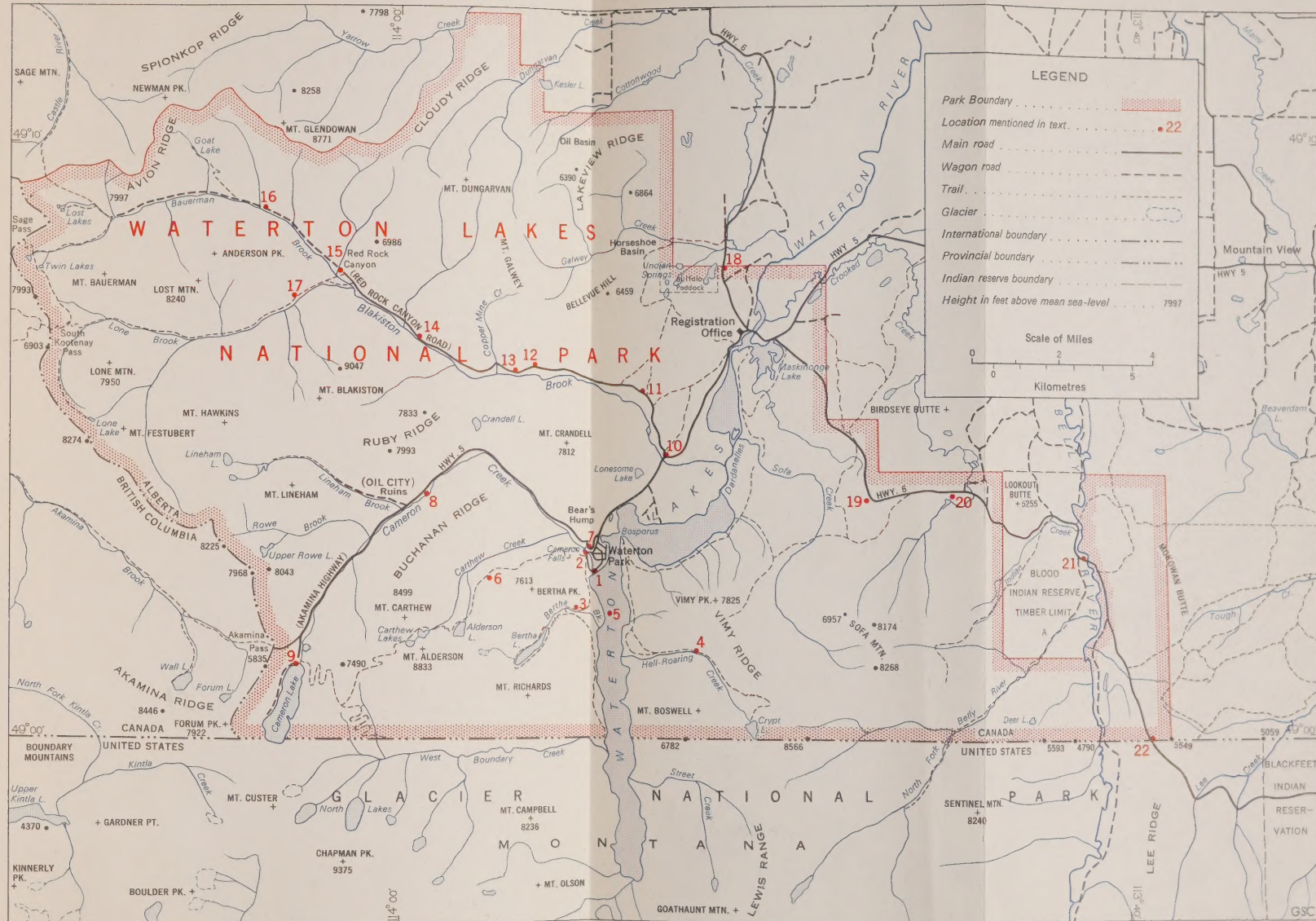
- Abrasion 63
- Akamina Brook 65
- Akamina Highway 59, 62, 64, 72
- Akamina Pass 66
- Alberta 1, 16, 29, 59, 66, 84
- Alberta-British Columbia
 - boundary 1, 3, 6, 66, 77, 78
- Alderson Lake 19, 21, 53, 54, 55, 57, 58
- Algal structures 19
- Alpine glaciers 26
- Altyn Formation 18, 22, 44, 46, 48, 50, 53, 59, 60, 86
- Amiskwi 34
- Ancient seas 7, 8, 9, 11, 12, 13
- Anderson Peak 19, 74, 77, 82
- Angle of repose 23
- Antarctica 25
- Anticlinal mountains 36
- Anticlines 36
- Appekunny Formation 18, 19, 22, 44, 49, 53, 59, 72
- Arctic Ocean 3, 4, 7, 13
- Arête 26
- Argillites 18, 19, 21, 22, 44, 56, 58, 59, 72, 73
- Atlantic Ocean 3, 4
- Banff National Park 4, 31, 33
- Basalt 21, 56, 58, 74
- Bauerman Brook 4, 77, 79
- Bear's Hump iv
- Bellevue Hill 69, 80, 81
- Belly River 84, 85
- Belly River Crossing 84, 85
- Belly River Formation 20
- Bertha Brook 18, 43, 44
- Bertha Lake 42, 44
- Bertha Peak .. 43, 47, 69, 82, 83
- Blakiston Brook 69, 70, 71, 72, 77, 78, 81
- Blakiston Falls 78
- Bleaching 19, 39, 52, 71, 73
- Botanical zones 53
- Boulders 69
- Boundaries, Waterton
 - Lakes Park 2, 3, 4
- Buchanan Ridge 65, 72
- Cameron Creek 38, 40, 42, 47, 50, 51, 59, 63, 72
- Cameron Falls 18, 29, 40, 42
- Cameron Lake 53, 59, 65, 66, 67
- Canyon 42, 53, 63, 75
- Carthew Creek 55
- Carthew Lakes 8, 19, 21, 53, 54, 55, 57, 58, 66
- Castle mountains 32
- Castle River 4
- Cathedral Peaks 33
- Chief Mountain 4, 20, 81, 82, 84, 87
- Cirques 2, 26, 28, 29, 37, 44, 45, 48, 49, 55, 65, 77
- Citadel Mountain 39, 52, 68
- Cliffs 47, 55, 72, 79
- Cloudy Ridge 4, 77
- Columbia River 6, 30, 59, 65

Complex mountains	36, 37	Folding	6, 11, 13, 17
Continental Divide	3, 4, 59,		30, 31, 72
	65, 77, 78, 80, 81	Foothills	29, 30
Copper	72	Formation	16
Copper Mine Creek	72	Fossils	9, 12
Crandell Lake	72	Fraser River	30
Crandell Peak	72	Front Ranges	29, 30, 31, 36
Cretaceous	20, 22, 82, 88	Frost action	23
Crypt Lake	44, 45, 46, 47,	Gabbro	19, 74
	48, 49, 51, 72	Galwey Creek	80
Delta	iv, 38, 42, 47, 50,	Geosynclinal mountains	7, 11, 14
	51, 59, 88	Glacial dam	66
Diabase	19	Glacial debris	71
Divide	2, 3, 78	Glacial outwash	48, 69, 70,
—see also Continental Divide			73, 86
Dogtooth mountains	34	Glacial till	24, 28
Dolomite	18, 21, 42, 44, 46,	Glaciation	25, 39, 55
	56, 60, 69, 86	Glacier National Park	iv, 84
Downsinking	11	Glaciers	14, 68, 88
Drill-holes	20	Goat Lake	77, 78
Erosion	11, 14, 15, 23, 24, 25,	Goathaunt Mountain	52
	28, 30, 32, 80, 81, 82, 87	Gorge—see Canyon	
glacier	11, 25, 27, 41, 43	Granite	11
river	11, 14, 23, 24	Great plains—see Plains	
wave	41	Greenland	25
Falls—see Waterfalls		Grinnell Formation	17, 18, 19,
Fans	70		22, 44, 53, 55, 72, 73
Fault slices	vi, 29, 30, 48,	Group	16
	53, 80, 81	Gulf of Mexico	7, 13
Fault trace	20	Gully	17
Faulting (faults)	vi, 11, 13, 15,	Hanging valley	26, 42, 50
	17, 30, 31, 36, 44, 53, 60, 62,	Hell Roaring Creek	17, 27, 29,
	82, 87, 88		47, 48, 50, 51
Finger lakes	26, 28	Hudson Bay	6, 65
Flathead River	6	Ice-cap	25, 39, 55
		Icefalls	49

Igneous rock	15, 19, 21, 22, 39, 52, 55, 56, 71, 72, 73, 77	Mount Campbell	68
Inland sea	38	Mount Carthew	66
International Boundary	39, 44, 50, 66, 67	Mount Cleveland ..	19, 39, 52, 53
Irregular mountains	35	Mount Crandell ..	37, 47, 51, 69, 72, 73, 80, 82
Jasper National Park	4, 31, 36, 37	Mount Crandell thrust	17, 22, 48, 59, 60, 61, 68
Kintla Creek	65	Mount Custer	67
Kintla Formation	19, 56, 58, 59, 66	Mount Dungarvan	33, 80, 81
Kootenay River	30	Mount Edith Cavell	33
Lake of the Woods	50	Mount Eisenhower	33
Lakeview Ridge	80	Mount Galwey	69, 72, 80, 81
Lava	6, 18	Mount Kerkeslin	36
Law of superposition	16	Mount Richards	52, 68
Layer-cake mountains	32	Mount Rundle	33
Lewis thrust	5, 20, 22, 31, 68, 69, 80, 82	Mount Saskatchewan	33
Lichens and mosses	53, 56	Mount Stephen	33
Limestones	18, 21, 32, 48, 56, 63, 68, 69, 74	Mountains, dipping layered rocks	33
Lone Lake	80	Mountains, fault-block	7
Lost Lakes	77	Mountains, folded	7
Main Ranges	29, 30	Mountains, geosynclinal	7, 11, 14
Manitoba	29	Mountains, irregular	35
Matterhorn	26, 37	Mountains, layer-cake	32
Mexico	7	Mountains, shapes of	31
Molten rock	11, 14	Mud cracks	12
Montana	4, 20, 68, 81, 82, 84, 85, 87	Oil	64
Mount Alderson	34, 68, 82	Oil City	63, 64
Mount Anderson	73	Outlier	81, 87
Mount Assiniboine	26, 37	Outwash	60
Mount Blakiston ..	19, 33, 71, 72, 73, 74, 75, 76, 77, 82	Pacific Ocean	3, 4, 6, 65
		Pilot Mountain	33
		Pincher Creek	80
		Pinnacles	33, 52, 69
		Plains	5, 30, 59, 80, 81, 88

- Potholes 75
 Precambrian vi, 8, 18, 38,
 63, 64, 66, 87
 Purcell Series 18, 19, 38
 Quartzite 18, 19, 32, 56
 Red beds 44, 60, 68, 76
 Red Rock Canyon 19, 68, 71,
 73, 75, 76, 78, 82
 Red Rock Canyon Road 68,
 69, 70, 71, 81
 Ripple marks 8, 11, 12, 52,
 56, 58, 63, 74, 88
 Rock tunnel 46
 Rocky Mountains vi, 3, 7, 12,
 13, 14, 29, 30
 Rocky Mountain Trench 30
 Ruby Peak 72
 Ruby Ridge 19, 35
 Sage Pass 78
 Sandstone 20, 32, 58
 Saskatchewan River 6, 65
 Sawback Range 34
 Sawtooth mountains 34
 Scree 23, 24, 48, 49, 54, 56,
 58, 69, 71, 75, 84
 Sea-level 7, 9
 Sedimentary rocks 9, 11, 52
 Shale 20, 32, 66
 Shapes of Mountains 31
 Sheppard Formation 19, 58
 Sills 19, 39, 52, 72, 74, 77
 Siltstones 76
 Siyeh Formation 18, 21, 44,
 53, 55, 57, 58
 Slate 32
 Snowslides 69, 72, 75, 77, 82
 Sofa Mountain 81, 84
 South Saskatchewan River .. 84
 Spikes—see Pinnacles
 Synclinal mountains 35
 Syncline 35, 36
 Stratification 52
 Stratum 16
 Talus 23, 24,
 —see also Scree
 Tarns 28
 Terrace 86
 Thrust fault vi, 20, 31,
 59, 63, 82
 Thrust sheets 37, 61, 64,
 69, 82, 87
 Thrust surface 59
 Till-boulders 73
 Twin Lakes 77, 78, 79, 80
 U-shaped valley 26, 28, 41
 United States vi, 19, 66, 67,
 84, 85
 —see also International
 Boundary
 Valleys 15, 23, 25
 Vancouver 50
 Vegetation patterns 72, 77
 Volcanic mountains 6
 Vimy Peak vi, 5, 17, 19, 22,
 37, 59, 60, 61, 68, 81, 83, 86
 Wapiabi Formation 20
 Warden's Station 77, 84
 Waterfalls 27, 38, 40, 42, 45,
 47, 48, 50, 53, 63, 78
 Waterton Formation .. 16, 17, 18,
 42, 44, 46, 53, 60

Waterton Lakes iv, vi, 18, 27, 28, 38, 39, 40, 41, 43, 44, 45, 50, 51, 53, 65, 68, 81, 83, 84, 86, 89	Waterton River 5
Waterton Lakes Park iv, vi, 16, 18, 19, 22, 29, 32, 38, 40, 42, 47, 50, 59, 61, 62, 82	Wave action 8, 50, 63
	Western Ranges 29, 30
	Winnipeg 50
	Yarrow Creek 4
	Yoho National Park 34



GSC Miscellaneous Report 10